A Treatise on Milling and Milling Machines

THE CINCINNATI
MILLING MACHINE COMPANY,
CINCINNATI, OHIO, U. S. A.

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A TREATISE

ON

MILLING

AND

MILLING MACHINES

THE CINCINNATI MILLING MACHINE CO.

CINCINNATI, OHIO, U. S. A.

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PREFACE.

This treatise is published in answer to a demand from those wishing to become more familiar with the construction and use of milling machines. The important parts of the Universal and Plain Milling Machines are clearly and concisely described. A number of examples of milling operations are shown to illustrate the advantages which these machines possess for manufacturing purposes.

INTRODUCTION.

THE use of Milling Machines during the past few years has been largely extended, as the advantages they possess for certain classes of work have become better understood. At the same time, great improvements have been made in the construction of these machines to adapt them to a larger variety of work. The constant aim of the designer has been to increase the range of these machines with the result that to-day they are used on work that a few years ago was thought not possible to be done on milling machines. Specialization in their manufacture has also contributed to this result. For many years we have confined our attention exclusively to that type of milling machines which is known as the pillar and knee type, comprising two classes, viz., Plain and Universal. In this way it has been possible for us to develope every detail of design and workmanship to a high degree of excellence. Our buildings are modern and well lighted and of ample size to afford an economical arrangement of machinery. Our machinery is modern, much of it being of our own design and especially adapted to our particular requirements. Jigs and special fixtures are employed throughout to insure both economy in manufacture and interchangeability of parts. We extend a cordial invitation to any one interested in metal working machinery to visit us. This will afford an opportunity of becoming more familiar with the use of milling machines, as developed on our own work, and at the same time, permit intending purchasers of milling machines, to thoroughly acquaint themselves with the merits which our machines possess, both as to design and workmanship.

THE CINCINNATI MILLING MACHINE CO.

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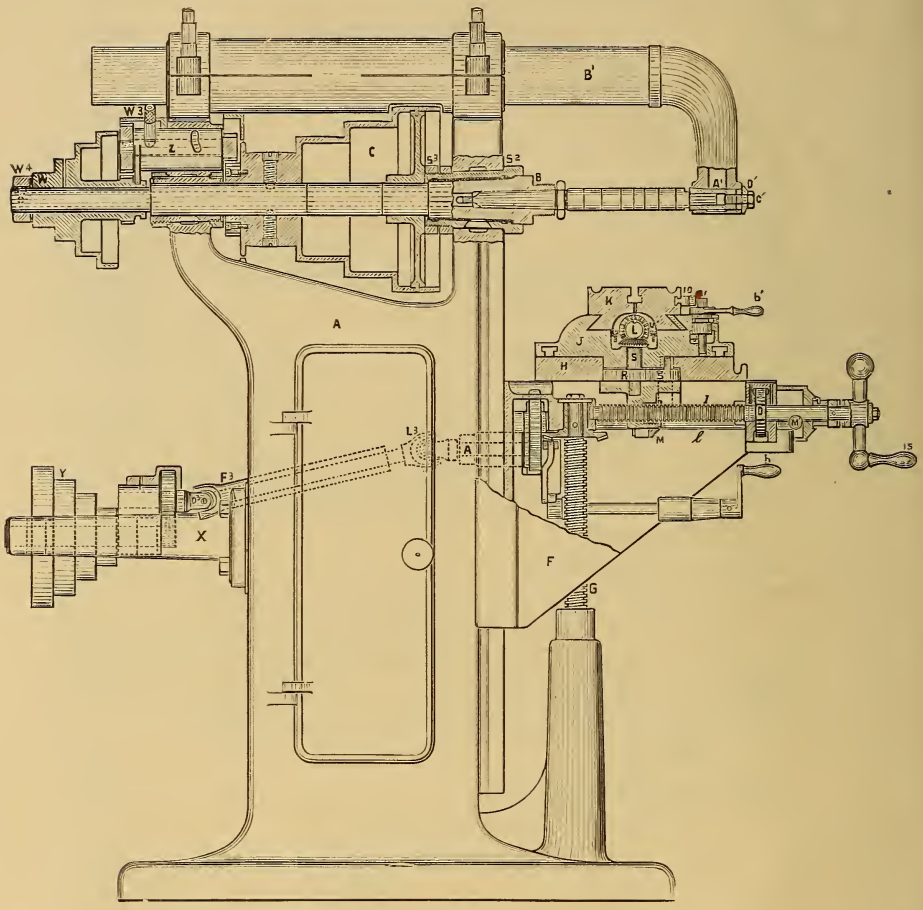


FIG. 1.

No. 1 UNIVERSAL.

Universal.

The name "Universal" applied to Milling Machines is now understood to designate a machine adapted to the automatic cutting of spirals. The swivel carriage in this machine swivels on its saddle, permitting the table to be turned to any angle.

The following description applies to the No. 1 Universal Milling Machine. We select this small machine for detail description as it embodies nearly all the features found in our other universal machines. This machine is completely universal in all its movements. The table may be completely revolved through 360 degrees, allowing spirals to be cut beyond 45 degrees.

Automatic Feeds.

The feeds are automatic in their horizontal directions, are reversible without crossing the feed-belt, and can be automatically tripped in either direction.

This size finds its greatest usefulness in the tool-room, as every kind of operation can be performed upon it, which can be performed upon the larger sizes of the Universal machines. Owing to its small size, it is quickly handled, and is therefore a favorite for tool-room work.

Over-hanging Arm.

An overhanging arm is provided for the better support of the outer end of the cutter arbor. In case an end mill is used, or where the character of the work does not require the overhanging arm, it is easily turned up out of the way.

Cutter Arbor.

The end of the arbor, which is made cylindrical and ground after hardening, has its support in the phosphor bronze bearing secured in the overhanging arm.

Bearing in Over-hanging Arm.

The bearing is so constructed to admit of being concentrically closed in as wear takes place. This feature is of no secondary importance, as by means of this improved bearing a close adjustment on end of arbor is obtained, firmly supporting it and permitting therefore heavy and accurate work to be done.

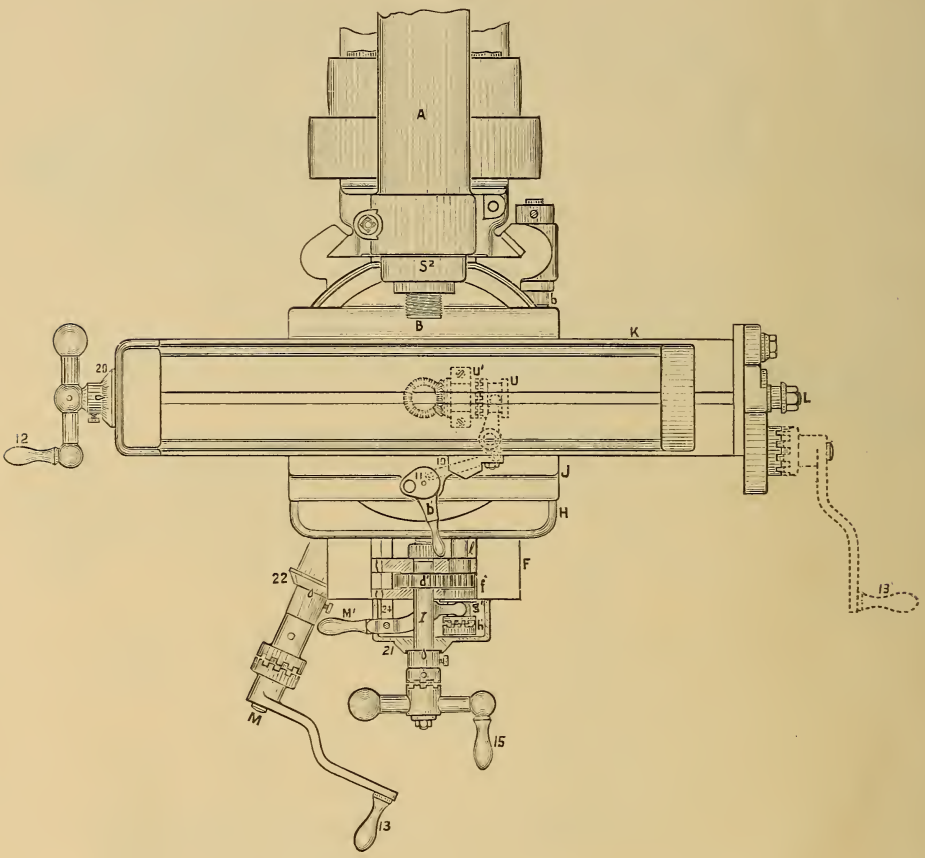


FIG. 2.

Countershaft Pulleys.

Two friction pulleys are furnished on countershaft, both running in same direction and at different speeds, giving double the usual number of spindle speeds. All spindles revolve in a right hand direction, permitting the use of turret machine, lathe and drill press tools. The double speed countershaft affords two speeds for the cutter without shifting the belt on cone pulley or changing the gearing, thus giving a roughing cut at one speed and a light finishing cut at a higher speed, very often a convenience to the operator.

Spindle.

The main spindle is made of crucible steel and has a $\frac{13}{16}$" hole bored through its entire length; the front end is bored to receive a No. 10 B. & S. taper shank on cutter arbors. The end of spindle is threaded for receiving the 6 inch universal chuck. The thread on the front end of the spindle is protected when not in use by a guard-collar.

Universal Chuck

The 6-inch universal chuck furnished is also made to fit the spindle of universal indexing and dividing head. Besides the numerous uses on the dividing head, it may be used on the main spindle of machine for holding straight shank reamers, drills, special milling cutters and boring bars, as well as for cutting up stock from the bar passed through the hollow spindle.

Front Box

The front box for spindle is solid and has a taper seat in the column. It is made of cast-iron and is lined with genuine Babbitt metal, thoroughly compressed and secured. The superiority of such a bearing is well recognized. Both front and back bearings are provided with lock nuts for taking up wear.

Back Box.

The back bearing is made of phosphor bronze, turned to fit a taper bored seat in the column.

Taking up wear of Boxes.

The taking up of the end wear of main spindle is provided for in the construction of the front box S^2, Fig. 1; on the rear end of this box is a threaded lock collar S^3, which may be screwed back against the hub of the cone pulley as wear takes place.

Oiling of Boxes. The two spindle boxes are oiled through a wick from a reservoir or chamber surrounding each journal, affording at all times ample lubrication.

Column. Knee. The main frame or column A, Fig. 1, is of box form with its face side planed to receive the knee F, which slides vertically upon it and is raised and lowered by

Vertical Screw. the screw G. Screw G is operated by a pinion shaft which has on the outer end a detachable clutch handle 13, Fig. 2, conveniently located for the workman.

Saddle. On top of the knee F, Figs. 1 and 2, the saddle H is placed. It is operated by the transverse feed screw 1, Fig. 1, in a line parallel to the axis of main spindle.

Swivel Carriage. The swivel carriage J, is placed on top of saddle. Its large bearing on the saddle provides a substantial support for the table K, at whatever angle the table may be placed. The swivel carriage is circular in form. This feature is of special value when cutting spirals or any work requiring the setting of the table to any considerable angle. The angular positions of the table are indicated by easily read graduations.

Clamping Carriage and Saddle. The swivel carriage is firmly clamped to the saddle by means of T-head bolts, which engage in a circular T-slot in swivel carriage. These bolts extend through the saddle and the nuts for tightening are easily accessible.

Oil Channels. The table has oil-channels along both sides which drain all oil drippings to the pockets at its ends. These oil-pockets are provided with plugs for draining the oil.

Table Feed. The power for driving the table is obtained from the four step cone pulley on the rear end of the main spindle B. For the slower feeds, this pulley is clutched directly to the spindle, and for the faster feeds, runs loose on the spindle. While loose on the spindle, the cone pulley is driven by a gear arrangement which increases the rate of feed between two and three times. For this heavier duty of rapid feeding, a higher belt speed is obtained.

By the one operation of raising handlever a^3, these gears are thrown out, and at the same time, the clutch on the cone pulley W, is engaged with the clutch a^4 on end of spindle, or *vice versa*.

Feed Changes.

There are eight changes of feed, varying from .004″ to .070″ travel of the table to one revolution of the cutter spindle. A dial on the guard for the feed mechanism indicates in plain figures the rate at which the machine is feeding.

Feed Belt.

The arm X, which carries the lower feed cone Y, can be conveniently adjusted on the column to keep the feed belt (which may be made endless), at a proper tension.

Feed Mechanism.

Motion is transmitted from cone Y, by means of the universal, jointed, telescope shaft to the stem gear *b*, Fig. 2, which has its bearing in the back of the knee F ; thence, to the splined shaft *l*, Figs. 1 and 2.

The direction of the power feeds is changed by operating the tumbler gears through the crank *h*, Fig. 1. These tumbler gears control the direction of rotation of shaft *l*.

Power Cross-feed.

The automatic operation of the cross feed is as follows. The splined shaft *l*, Fig. 2, has a clutch h^1, pinned to its outer end for engaging with another clutch g^1, attached to a pinion f^1.

The automatic cross feed is thrown in or out by means of hand-lever M^1, Fig. 2, engaging or disengaging clutch h^1. This feed may be thrown out automatically by means of trip-dogs which act on pitman 24, Fig. 2, to disengage h^1.

The cross-feed screw I, receives its power feed from the pinion f^1, by its attached gear d^1, Fig. 2. A clutch-handle 15, Fig. 2, on end of cross-feed screw, mounted loosely on it, is shifted into engagement for operating this feed by hand.

Power Table-feed.

The motion for feeding the table is taken from the same splined shaft *l*, Fig. 1, which has upon it a sliding bevel gear M, engaging into its companion on a vertical shaft, on the upper end of which is formed a spur

pinion q. Gear q engages with the large gear r on shaft s, centrally located within the carriage J. On the upper end of this shaft is a bevel gear meshing with gear U^1. Gear U^1 is journaled in the carriage and has clutch teeth for engaging a feathered clutch U, Fig. 2, sliding on the feed screw L, and operating it. The hand lever b^1, engages and disengages clutch U, for starting and stopping the automatic table feed.

Dog on Table. In the T-slot on the front side of the table is an adjustable feed tripping dog, 10. This dog has two wedge surfaces, either of which as it approaches the stud 11 on the lever b^1 swings the lever b^1 which disengages the feather clutch U, and instantly stops the table-feed.

Back Lash. Back-lash in the table feed screw is overcome by the use of a compensating nut.

Handles on Table. There is a handle provided on each end of the table for feeding it by hand. The handle 12, Fig. 2, on left end of table, is used for fine feeding, the other 13^1, Fig. 2, on right end is used for rapid feeding and also for a quick return of the table.

Elevating Shaft. The shaft M for vertical motion is placed at an oblique angle, and carries a clutch crank 13. This arrangement of shaft in connection with permanent handles on screws for cross and longitudinal adjustments of table, gives the operator easy control of every adjustment without the necessity of changing his position or shifting the handles.

Adjustments. Two adjustments may be made simultaneously. All adjustments are indicated in the thousandths of an inch by large readable dials, 20, 21, 22, Fig. 2.

UNIVERSAL INDEXING AND DIVIDING HEAD.

Use. The Universal Indexing and Dividing Head is used for cutting spiral work such as twist drills, spiral teeth on cylindrical and conical milling cutters, and teeth in spiral gear wheels, etc. It is used to the greatest extent for indexing and dividing the periphery of cylindrical work into a large range of a number of equal divisions.

Change Gears. When cutting spirals, suitable gears are attached from the lead screw to the dividing head. These gears are mounted on the segment plate Q, Fig. 3. When the table is driven by its lead screw, these gears produce rotation of the dividing head spindle.

Lead. On most spiral work, for every revolution of the dividing head spindle, the table travels more than one inch. Therefore, instead of designating the spiral by its pitch, the lead is given in inches, which means that the table has traveled a certain number of inches (called lead) while the dividing head spindle has made one revolution. For example, a 6-inch lead is one in which the dividing head spindle makes one turn in 6 inches travel of the table. The manner of determining the gears for various spirals is explained under the head of Change Gears for Cutting Spirals, in this treatise.

Housing. Fig. 3 shows the various parts of the head. The housing E rests on the table of the milling machine, and has two feathers which fit in the T-slot of the table and two slotted holes in its base for receiving two clamping bolts.

Swiveling Block. The swiveling block carrying the spindle S, is fitted in the housing E. This block is always fully contained within its bearings at whatever angle the spindle is held.

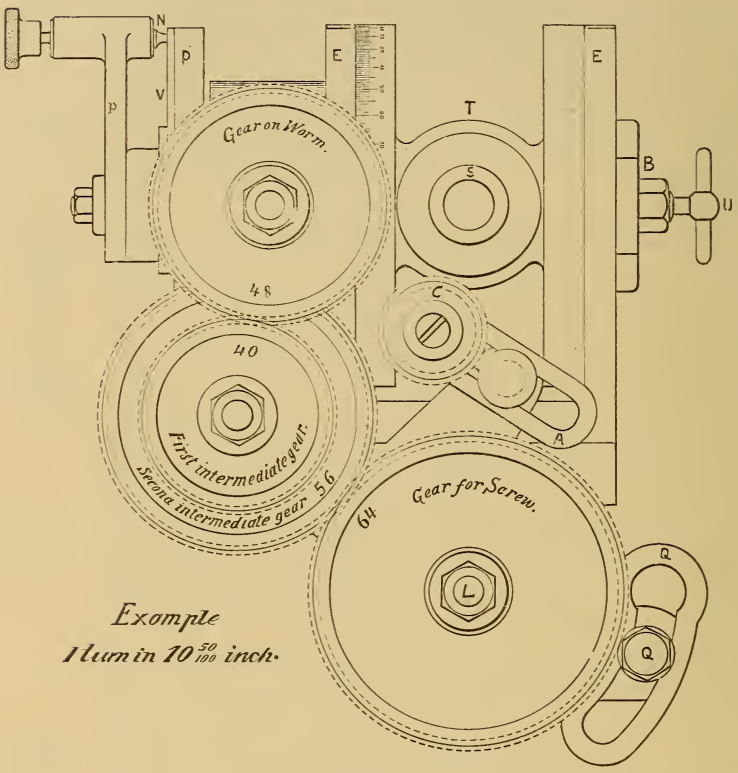

N
P
P
V
E
E
T
Gear on Worm.
48
S
B
U
C
40
First intermediate gear.
Second intermediate gear 56
A
64
Gear for Screw.
L
R
Q
Example
1 turn in 10 50/100 inch.

FIG. 3.

A circular T-slot, similar to that of a planer head, is turned in one side of the swiveling block. This slot is concealed, and can not become clogged with chips. By means of two T-bolts in this slot and an additional clamping device B, on the other side, the swiveling block is firmly held at any desired angle. The end of the spindle is not raised to an excessive height when it is in a vertical position, because the axis of the swiveling block is central with the housing. The swiveling block is as rigid when the spindle is vertical as in any other position.

Spindles.

The same arbors which fit the main spindle of the milling machine will fit the spindle S. The spindle S will take work through its entire length $1\frac{1}{16}''$ diameter. The front end of the spindle is threaded to receive a 6-inch universal chuck. When not in use, the thread on the spindle is protected by a guard-collar.

Chuck.

The chuck fitting this spindle also fits the main spindle of the machine. The spindle of the head is provided with a clamping device U, by means of which it can be firmly locked during cutting operations, thus relieving the worm, worm wheel and index pointer of all strain.

Clamping Spindle.

On the spindle, there is formed a worm gear having 40 teeth. For dividing work into a number of equal parts, the side index plate P^1, and index pointer N, are provided. A complete description of the method of making divisions is given in the article on the use of the sector, page 18.

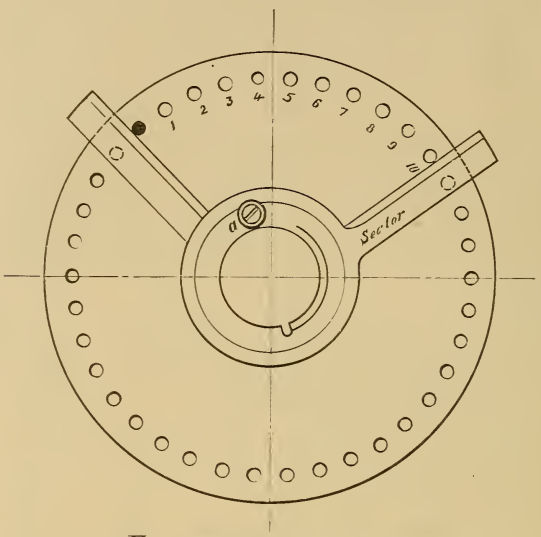
Index-plate and Index-pointer.

The sector is shown at V, Fig. 3, and more plainly in Fig. 4.

Sector.

To cut left hand spirals on the Nos. 1, 1½ and 2 Universal Machines, and right hand spirals on the No. 3 Universal Machine, the idle gear C is meshed between the change gears by shifting the holder A. This holder is marked for each machine, with the direction of the spiral which can be cut when the idle gear C is in mesh.

Direction of Spiral.



Example 152 Teeth

38 Circle 10 Holes.

FIG. 4.

SECTOR.

Fig. 4 shows how the sector is adjusted for counting off holes in the index-plate. This example shows the sector in position to cut 152 teeth which requires that the index pointer move over a series of 10 holes for each division. Mistakes are frequently made in setting the sector only 10 holes apart, which is incorrect. The hole in which the index-pointer rests, which is indicated by black spot, should never be counted when adjusting the sector for any number of holes. After the sector is set and tightened by the screw *a*, no further counting of holes is necessary in cutting the wheel of 152 teeth, because the sector as set is moved against the index pointer for each division.

The index-plate is drilled from both sides, the circles 18, 24, 28, 30, 34, 37, 38, 39 and 41, being drilled in one side and circles 42, 43, 46, 47, 49, 54, 58, 62 and 66 in the other.

With these circles, the greatest possible variety of divisions up to 360 is obtained as shown in table in the latter part of this book.

Rule. The following rule may be applied for finding the number of turns or number of holes required to divide the periphery of cylindrical work into any given number of equal parts.

Forty revolutions of the index-pointer holder P, Fig. 3, are required to make one revolution of the dividing head spindle; therefore, to make any part of a revolution of the spindle, 40 divided by the number of divisions required, will determine the number of turns or part of a turn to be made by the index pointer.

For example, suppose it is required to cut 96 teeth; then 40 divided by 96 is equal to $\frac{40}{96}$; according to the index chart furnished with each dividing head, this division can be made by using the 24 hole circle; since $\frac{40}{96}$ is equal to $\frac{10}{24}$, the index pointer must make $\frac{10}{24}$ of a turn or be moved 10 holes in the 24 hole circle for each division.

We are prepared to furnish index plates to make the special divisions shown on page 20, in addition to those which are shown on our regular table. On account of the greater number of holes in these plates, the holes must be drilled smaller than in the regular plate, and an index-pointer of smaller diameter is also required.

SPECIAL DIVISIONS.

No. of Teeth.	Circle.	Holes.	No. of Teeth.	Circle.	Holes.	No. of Teeth.	Circle.	Holes.	No. of Teeth.	Circle.	Holes.
51	51	40	102	51	20	204	51	10	408	51	5
53	53	40	106	53	20	212	53	10	424	53	5
57	57	40	114	57	20	228	57	10	456	57	5
59	59	40	118	59	20	236	59	10	472	59	5
61	61	40	122	61	20	244	61	10	488	61	5
63	63	40	126	63	20	252	63	10	504	63	5
67	67	40	134	67	20	268	67	10	536	67	5
69	69	40	138	69	20	276	69	10	552	69	5
71	71	40	142	71	20	284	71	10	568	71	5
73	73	40	146	73	20	292	73	10	584	73	5
77	77	40	154	77	20	308	77	10	616	77	5
79	79	40	158	79	20	316	79	10	632	79	5
81	81	40	162	81	20	324	81	10	648	81	5
83	83	40	166	83	20	332	83	10	664	83	5
87	87	40	174	87	20	348	87	10	696	87	5
89	89	40	178	89	20	356	89	10	712	89	5
91	91	40	182	91	20	364	91	10	728	91	5
93	93	40	186	93	20	372	93	10	744	93	5
97	97	40	194	97	20	388	97	10	776	97	5
99	99	40	198	99	20	396	99	10	792	99	5
101	101	40	202	101	20	404	101	10	808	101	5
103	103	40	206	103	20	412	103	10	824	103	5
107	107	40	214	107	20	428	107	10	856	107	5
109	109	40	218	109	20	436	109	10	872	109	5
111	111	40	222	111	20	444	111	10	888	111	5
113	113	40	226	113	20	452	113	10	904	113	5
117	117	40	234	117	20	468	117	10	936	117	5
119	119	40	238	119	20	476	119	10	952	119	5
121	121	40	242	121	20	484	121	10	968	121	5
123	123	40	246	123	20	492	123	10	984	123	5
125	125	40	250	125	20	500	125	10	1000	125	5
127	127	40	254	127	20	508	127	10	1016	127	5
128	128	40	256	128	20	512	128	10	1024	128	5
129	129	40	258	129	20	516	129	10	1032	129	5
131	131	40	262	131	20	524	131	10	1048	131	5
133	133	40	266	133	20	532	133	10	1064	133	5
137	137	40	274	137	20	548	137	10	1096	137	5
139	139	40	278	139	20	556	139	10	1112	139	5
141	141	40	282	141	20	564	141	10	1128	141	5
143	143	40	286	143	20	572	143	10	1144	143	5
147	147	40	294	147	20	588	147	10	1176	147	5
149	149	40	298	149	20	596	149	10	1192	149	5
151	151	40	302	151	20	604	151	10	1208	151	5
153	153	40	306	153	20	612	153	10	1224	153	5
157	157	40	314	157	20	628	157	10	1256	157	5
159	159	40	318	159	20	636	159	10	1272	159	5
161	161	40	322	161	20	644	161	10	1288	161	5
163	163	40	326	163	20	652	163	10	1304	163	5
167	167	40	334	167	20	668	167	10	1336	167	5
169	169	40	338	169	20	676	169	10	1352	169	5
171	171	40	342	171	20	684	171	10	1368	171	5
173	173	40	346	173	20	692	173	10	1384	173	5
175	175	40	350	175	20	700	175	10	1400	175	5
177	177	40	354	177	20	708	177	10	1416	177	5
179	179	40	358	179	20	716	179	10	1432	179	5
181	181	40	362	181	20	724	181	10	1448	181	5
183	183	40	366	183	20	732	183	10	1464	183	5
187	187	40	374	187	20	748	187	10	1496	187	5
189	189	40	378	189	20	756	189	10	1512	189	5
191	191	40	382	191	20	764	191	10	1528	191	5
193	193	40	386	193	20	772	193	10	1544	193	5
197	197	40	394	197	20	788	197	10	1576	197	5
199	199	40	398	199	20	796	199	10	1592	199	5

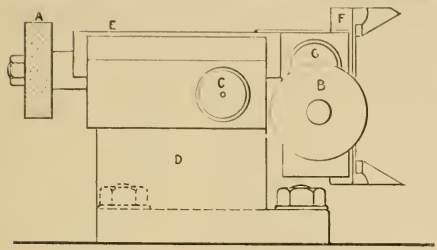


FIG. 5.

TAIL STOCK.

Housing.

Fig. 5 illustrates the tail-stock. The housing is shown at D. The slide E is dove-tailed into the housing and is moved forward and backward by turning the knob A.

Slide.

Clamping Bolt for Slide.

Center-bar.

Clamping Bolt for Center-bar

The clamping bolt C holds the slide E firmly in any position. The double center-bar F in tail-stock is dove-tailed into the front of the slide E. This center-bar is adjustable up and down by means of a rack and pinion operated by the knob B. The clamping bolt G, holds the center-bar firmly in any position.

Small Center.

Large Center.

One center has the top milled off to allow small work, such as taps, reamers, etc., to be milled; the other end is left as full as possible for milling heavy work with large centers.

The change from one end of the center-bar to the other is easily and quickly made.

Special Centers.

Fig. 6 shows a special tail-stock center-bar. One end A is milled off on the side as well as on the top. This permits the use of an end mill very close to the center. The other end of this center-bar is provided with a female center B.

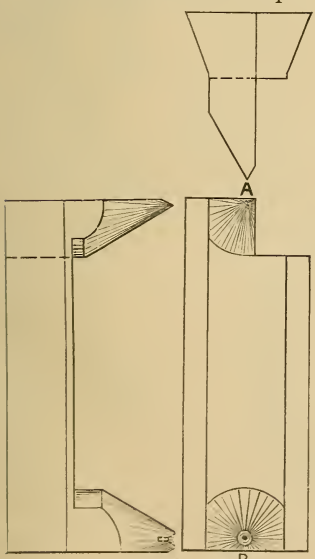


FIG. 6.

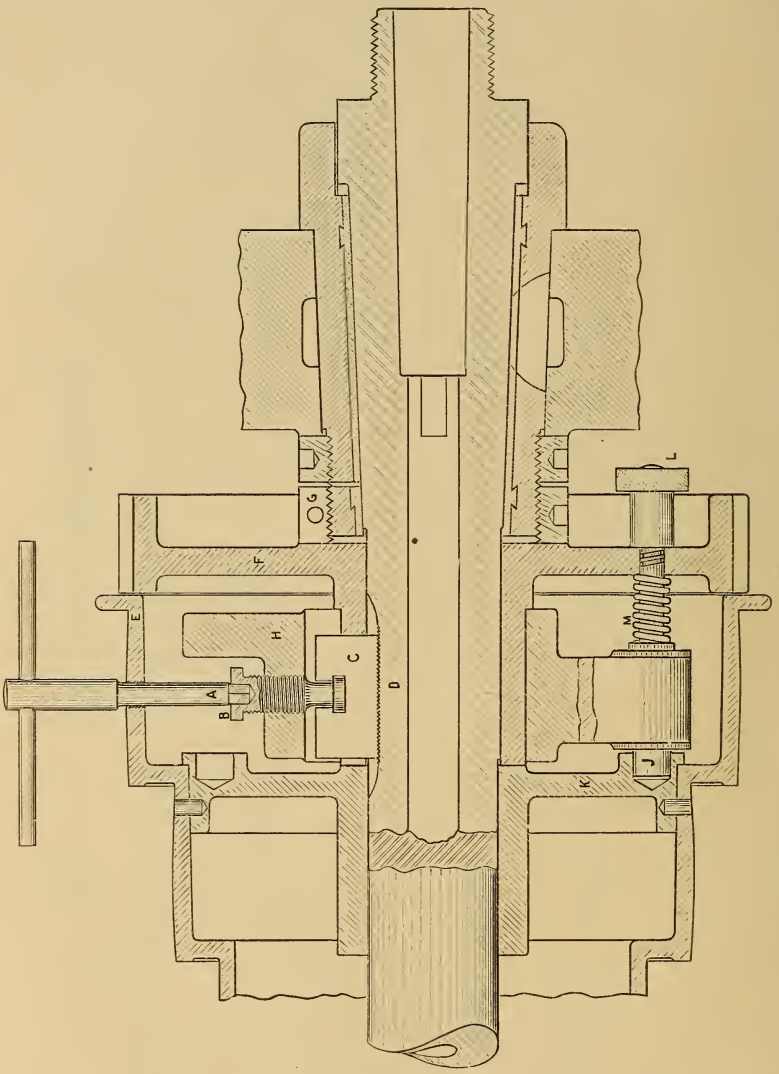


FIG. 7.

SPINDLE FOR BACK-GEARED MACHINES.

Fig. 7 shows the method of fastening the face-gear F, with its collar H, to the spindle by means of the notched feather C and spline in the spindle D.

The knurled knob L is used for connecting and disconnecting the face-gear F and the driving cone E. When the back-gear is not required, the face-gear and driving cone run together. To accomplish this, the knurled knob L is turned to the left, and by turning the driving pulley belt by hand, the driving stud J is pushed into one of the holes in the driving cone head K, by the spring M.

For disconnecting the face-gear from the cone, the driving stud J is withdrawn by turning the knurled knob L to the right, and the back-gear can then be thrown in. This knob avoids the use of a wrench, and enables the operator to make these changes without the necessity of feeling his way.

To Adjust the Spindle.—For taking up the wear on the taper of the spindle, and to take out end play, turn the lock-nut G toward the face-gear F.

After a number of adjustments of the spindle, the driving cone may become crowded against the back box. To move the cone forward, the notched feather C is withdrawn by turning screw B until it comes to a stop. Turn the lock-nut G away from the face-gear. Then move the face-gear and driving cone toward the nut G. Screw down the notched feather C, which will now engage in other teeth in the notched spline nearer the front of the spindle.

To take the Milling Machine Spindle D out of its bearings, insert wrench A through the largest step of the cone pulley into screw B, and withdraw feather C, until it comes to a stop, and after unfastening the gear on back end of spindle the spindle may be withdrawn.

The Cone Pulley E should have about $\frac{1}{32}$ of an inch lateral play after the spindle is adjusted.

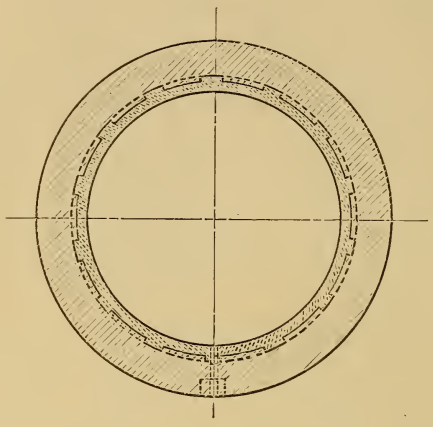


FIG. 8.

SECTION OF FRONT BOX.

Fig. 8 shows a section of the front cast iron box, with its Babbitt lining. After the box has been bored, dove-tail slots are planed lengthwise in it. Two dove-tail circular grooves are turned in it to keep the Babbitt metal from shifting lengthwise. The Babbitt metal is thoroughly compressed by a rolling process, then turned out true, and treated as though it were a solid box.

Babbit lined bearings have been used for many years on lathes, screw machines, and other fine and accurate machinery, and better results have been obtained from its use than from any other material.

GEAR-BOX.

All back-geared machines are made with a gear-box, providing a stronger and wider range of feeds for the heavier duty resulting from the use of cutters of larger diameters and wider faces, which may be used, owing to the increased range of spindle speeds.

Figs. 9 and 10 show the construction of the gear-box. A small and large pinion O and P, are secured on the rear end of the milling machine spindle B, which projects beyond the column. Pinions R and S, which mesh either with O or P, are fastened to shaft Q.

The gears T, U, V and shaft Q drive the cone pulley, W. From this pulley, power is transmitted to universal-jointed telescope shaft in the same manner as described on page 13.

On top of the gear-box is fastened a plate, I^3, showing the rate of feed in thousandths of an inch to one revolution of the main spindle.

The gears T and V are change gears, which may be transposed for slower or faster feeds. Twelve distinct changes in the rate of feed are obtained by the use of the cone pulleys, sliding gear and change gears. The gear, U, is an intermediate gear running loose on an eccentric bushing. No fine adjustment of the intermediate gear is necessary in transposing gears T and V, because the eccentric bushing is simply turned one-half revolution to bring the gears into proper mesh. The dial plate, I^3, and the pointer, H^3, are shown below.

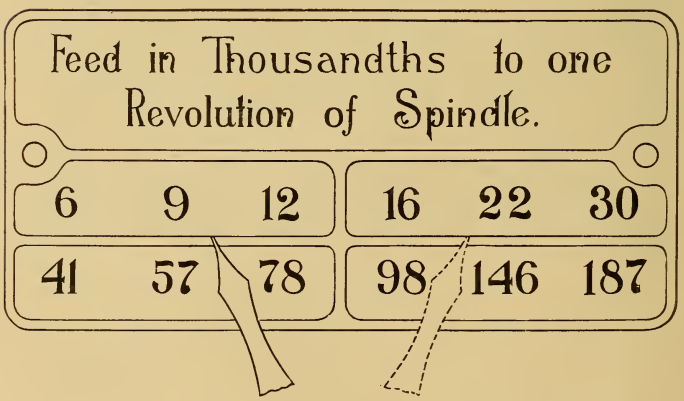
The rate of feeds is read from the plate as follows. When the small gear V is on the upper shaft Q, and the belt is on the smallest step of the cone pulley, W, the left hand figure in the upper row, on the side to

which the pointer directs, should be read; if the belt is on the second step of the cone pulley, W, the second figure, and if on the third step, the third figure in the upper row is read. When the large gear, T, is on shaft, Q, the lower row of figures is read in the same manner.

For example, when the feed belt is running on the small step of the pulley, W, and the pointer, I^3, points to the left, this would indicate that the feed advances $\frac{6}{1000}$ of an inch to every revolution of the milling cutter. Throwing the lever to the left, thereby shifting the sliding gear inside the box, and changing the direction of the pointer to the right, the rate of feed indicated will be $\frac{16}{1000}$ of an inch.

By placing the belt on the second step of the cone pulley, the second number, 9 is read, and by throwing the lever over, the pointer indicates $\frac{22}{1000}$ of an inch feed to every revolution of the spindle.

This rapid change in the rate of feed by simply throwing the lever, G^3, from one side to the other is quite an advantage because coarse and fine feeds can be applied on some work for roughing and finishing cuts without rechucking the piece.



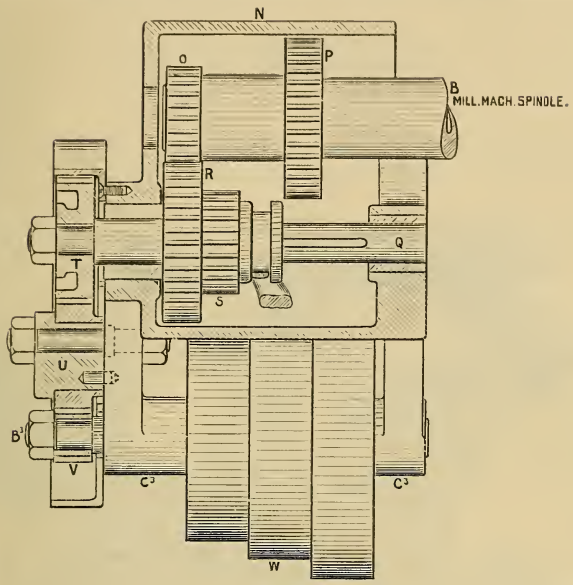

N
O
P
B
MILL. MACH. SPINDLE.
R
Q
T
S
U
B³
V
C³
C³
W

FIG. 9.

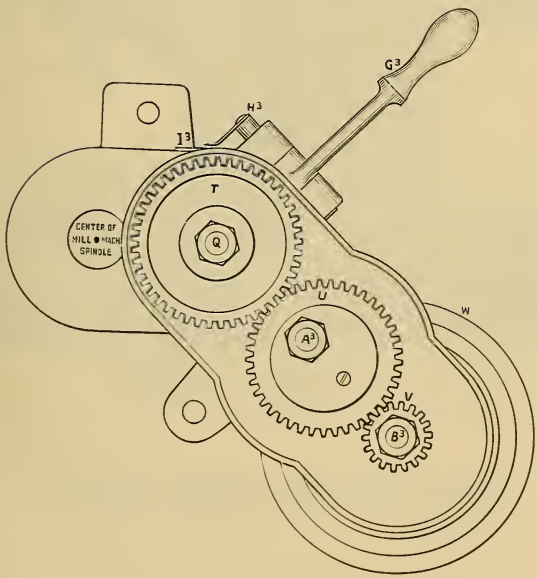
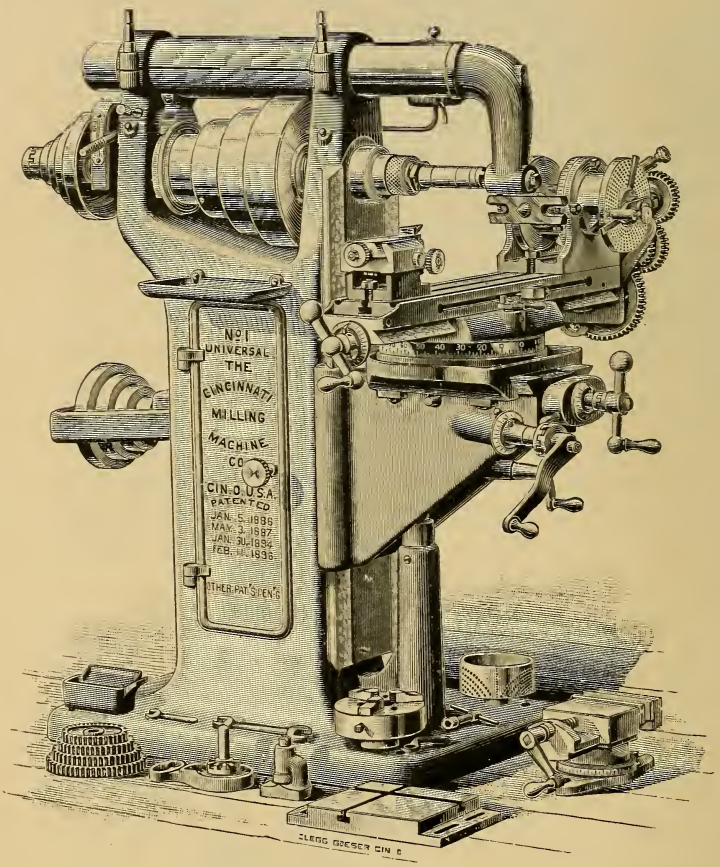

G³
H³
I³
T
CENTER OF MILL MACH SPINDLE
Q
U
W
A³
B³

FIG. 10.

Table Feed,	.	20 in.
Cross "	.	6 in.
Vertical "	.	17 in.



No. 1 Universal Milling Machine.

FIG. 11.

No. 1 UNIVERSAL.

The No. 1 Universal is well adapted for the tool-room. Its size permits a rapid adjustment of the machine for the great variety of work usually performed there.

The Spindle is bored to receive a No. 10 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{3}{16}''$ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 3″ belt. The largest diameter is 12 inches.

The Overhanging Arm is $3\frac{3}{4}''$ diameter. It can be turned up out of the way or put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is $6\frac{1}{4}$ inches.

The Table over all including oil pockets is $35'' \times 6\frac{1}{2}''$. The working surface is $33'' \times 6\frac{1}{2}''$. There is one T-slot $\frac{5}{8}''$ wide. The top of the table can be lowered 17″ below the center of the spindle.

The Swivel Carriage which forms the housing for the table is graduated in degrees on its circular face. A T-slot is turned in the bottom, near the outer edge, to receive two T-bolts which pass down through the saddle and are used for firmly clamping the swivel carriage to the saddle.

The Feed of the table is automatic in either direction through 20″. The cross motion in line with the spindle is 6″, and is automatic in either direction. Both of the above feeds are reversed by a lever on the front of the machine, without crossing the feed belt There are 8 changes of feed which vary from .004″ to 070″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch.

The Index Cutters furnished with this machine swing 10″ diameter and take in length 15 inches.

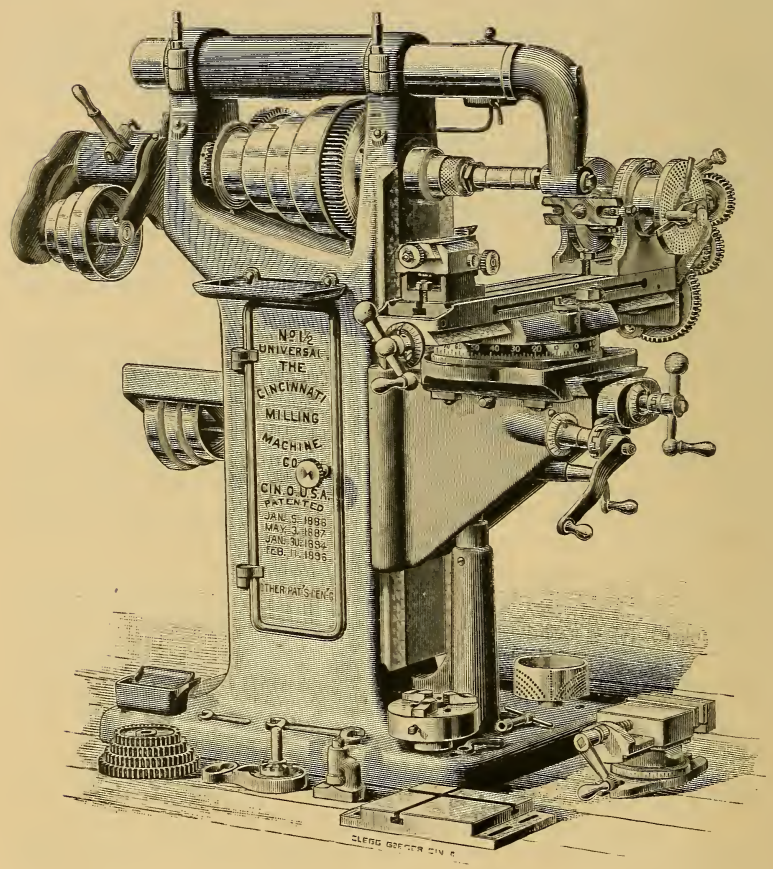
The Vise can be swiveled to any position, the angle of which is shown on the graduated base. The jaws are 6″ wide, $1\frac{7}{16}''$ deep, and will open $3\frac{1}{2}''$.

The Countershaft has two 12 inch friction pulleys for 3″ belts, which should run at 80 and 110 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 69 x 58 inches.

Net Weight of machine is 1900 pounds.

Table Feed,	.	20 in.
Cross "	.	6 in.
Vertical "	.	17 in.



No. 1½ Universal Milling Machine.

FIG. 12.

No. 1½ UNIVERSAL.

The No. 1½ Universal Milling Machine closely resembles the No. 1 Universal. It is provided, however, with back-gearing and the feed gear-box described on page 25.

This machine is well adapted for tool-room work where more spindle power and a larger range of spindle speeds is required.

The Spindle is bored to receive a No. 10 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{13}{16}$″ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 2½″ belt. The largest diameter is 10 inches.

The Overhanging Arm is 3¾″ diameter and can be turned up out of the way or put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is 6¼ inches.

The Table over all including oil pockets is 35″ x 6½″. The working surface is 33″ x 6½″. There is one T-slot ⅝″ wide. The top of the table can be lowered 17″ below the center of the spindle.

The Swivel Carriage which forms the housing for the table is graduated in degrees on its circular face. A T-slot is turned in the bottom, near the outer edge, to receive two T-bolts which pass down through the saddle and are used for firmly clamping the swivel carriage to the saddle.

The Feed of the table is automatic in either direction through 20″. The cross motion in line with the spindle is 6″, and is automatic in either direction. Both of the above feeds are reversed by a lever on the front of the machine, without crossing the feed belt. There are 12 changes of feed which vary from .006″ to .150″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch.

The Index Centers furnished with this machine will swing 10″ diameter and take in length 15 inches.

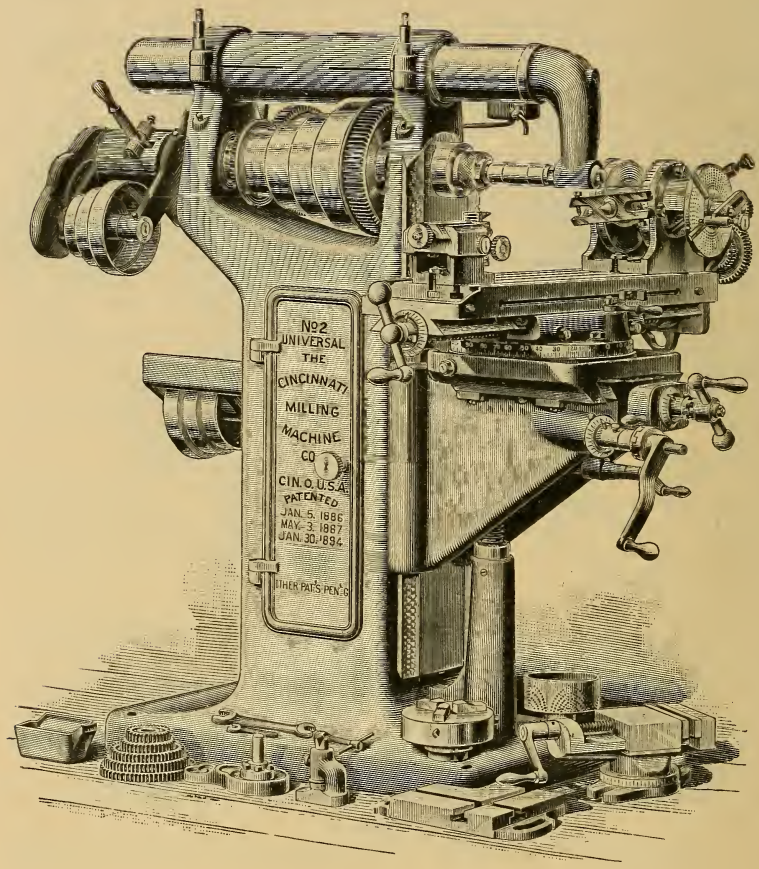
The Vise can be swiveled to any angle, where its position is shown by the graduated base. The jaws are 6″ wide, $1\frac{7}{16}$″ deep, and will open 3½″.

The Countershaft has two 12 inch friction pulleys for 3″ belts, which should run at 90 and 150 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 69 x 58 inches.

Net Weight is 1980 pounds.

Table Feed,	.	23 in.
Cross "	.	6½ in.
Vertical "	.	18½ in.



No. 2 Universal Milling Machine.

FIG. 13.

No. 2 UNIVERSAL.

The No. 2 Universal is adapted for tool-room work and can be placed to good advantage in jobbing shops. It is heavier than the Nos. 1 and and 1½ Universal and has a larger range throughout. This machine is back-geared.

The Spindle is bored to receive a No. 10 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{13}{16}$″ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 2¾″ belt. The largest diameter is 10 inches.

The Overhanging Arm is 4″ diameter. It can be turned up out of the way or put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is $5\frac{9}{16}$ inches.

The Table over all including oil pockets is 38″ x 8⅜″. The working surface is 35″ x 8⅜″. There are two T-slots ⅝″ wide. The top of the table can be lowered 18½″ below the center of the spindle.

The Swivel Carriage which forms the housing for the table is graduated in degrees on its circular face. A T-slot is turned in the bottom for one of the T-head clamping bolts.

The Saddle has a T-slot turned in its upper face which, in connection with the T-slot in the swivel carriage, permits the use of four strong bolts for firmly clamping the swivel carriage and saddle together.

The Feed of the table is automatic in either direction through 23″. The cross motion in line with the spindle is 6½″, and is automatic in either direction. Both of the above feeds are reversed by a lever on the front of the machine, without crossing the feed belt. There are 12 changes of feed which vary from .006″ to .150″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch An automatic vertical feed can be furnished with this machine to order.

The Index Centers swing 10″ diameter and take in length 17 inches.

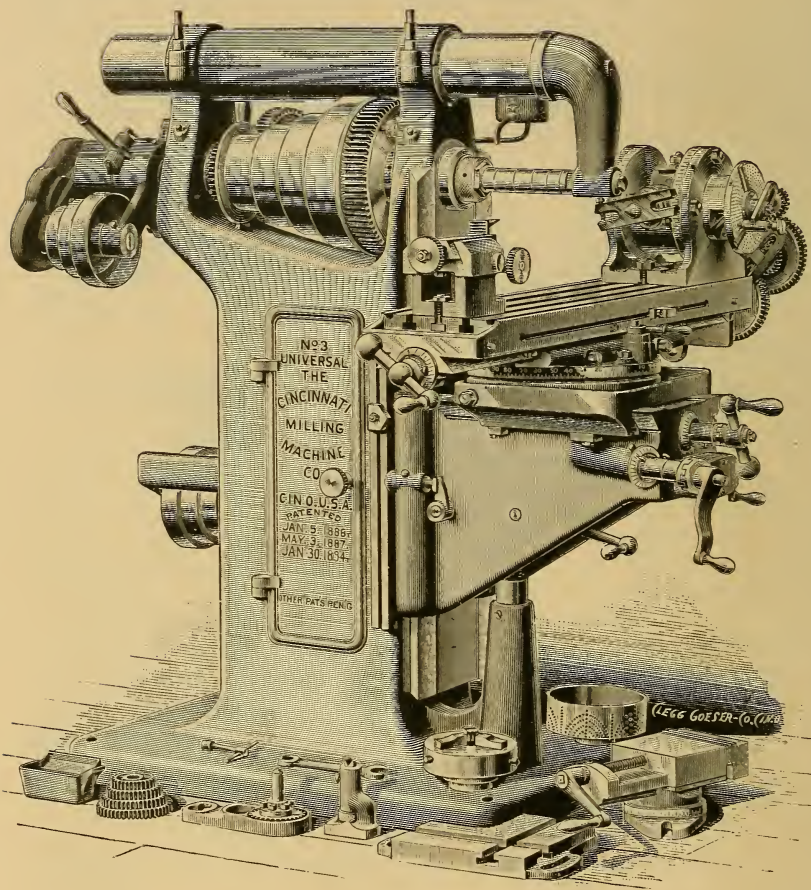
The Vise can be swiveled to any position, the angle of which is shown by the graduated base. The jaws are 6″ wide, $1\frac{7}{16}$″ deep, and will open 3½″.

The Countershaft has two 12 inch friction pulleys for 3½″ belts, which should run at 90 and 150 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 82 x 68 inches.

Net Weight is 2125 pounds.

Table Feed,	.	28 in.
Cross "	.	7½ in.
Vertical "	.	19 in.



No. 3 Universal Milling Machine.

FIG. 14.

No. 3 UNIVERSAL.

The No. 3 Universal is much heavier and is more powerful than the smaller sizes. It is intended for a heavier class of tool-room work and is very useful for general manufacturing purposes where a Universal Machine is required. This machine is back-geared.

The Spindle is bored to receive a No. 11 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{3}{16}''$ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 3″ belt. The largest diameter is 11½ inches.

The Overhanging Arm is 4½″ diameter and can be turned up out of the way or put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is $6\frac{7}{16}$ inches.

The Table over all including oil pockets is 46″ x 9½″. The working surface is 43″ x 9½″. There are 3 T-slots ⅝″ wide. The top of the table can be lowered 19″ below the center of the spindle.

The Swivel Carriage which forms the housing for the table is graduated in degrees on its circular face. A T-slot is turned in the bottom for one of the T-head clamping bolts.

The Saddle has a T-slot turned in its upper face which, in connection with the T-slot in the swivel carriage, permits the use of four strong bolts for firmly clamping the swivel carriage and saddle together.

The Feed of the table is automatic in either direction through 28″. The cross motion in line with the spindle is 7½″ and is automatic in either direction. Both of the above feeds are reversed by a lever on the front of the machine, without crossing the feed belt. There are 12 changes of feed which vary from .006″ to .150″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch. An automatic vertical feed can be furnished with this machine to order.

The Index Centers furnished with this machine swing 12″ diameter and take in length 21 inches.

The Vise can be swiveled to any position, the angle of which is shown by the graduated base. The jaws are 7″ wide, $1\frac{7}{16}''$ deep, and will open 4¼″.

The Countershaft has two 12-inch friction pulleys for 3½″ belts, which should run at 90 and 150 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 98½″ x 72″.

Net Weight is 2800 pounds.

GENERAL DIMENSIONS.

UNIVERSAL MILLING MACHINES.

	Page 28	Page 30	Page 32	Page 34
	No. 1.	**No. 1½.**	**No. 2.**	**No 3.**
Net weight	1900 lbs.	1980 lbs.	2100 lbs.	2800 lbs.
Shipping weight about	2400 lbs.	2500 lbs.	2700 lbs.	3400 lbs.
Length of automatic feed to table	20″	20″	23″	28″
Cross motion in line with spindle	6″	6″	6½″	7½″
Vertical range	17″	17″	18½″	19″
Size of table over all	35x6½″	35x6½″	38x8⅜″	46x9½″
Working surface of table	33x6½″	33x6½″	35x8⅜″	43x9½″
Largest diameter of driving pulley	12″	10″	10″	11½″
Number of steps on driving pulley	4	4	4	4
Number of spindle speeds	8	16	16	16
Width of driving belt	3″	2½″	2¾″	3″
Number of feed changes	8	12	12	12
Variations in feed to 1 rev. of spindle	.004 to .070	.006 to .150	.006 to .150	.006 to .150
Width of feed belt	1¼″	1½″	1½″	1½″
Center of spindle to overhanging arm	6¼″	6¼″	$5\frac{9}{16}$″	$6\frac{7}{16}$″
Diameter of overhanging arm	3¾″	3¾″	4″	4½″
Back-geared	No.	Yes.	Yes.	Yes.
No. of vise furnished	1 Swiv.	1 Swiv.	1 Swiv.	2 Swiv.
No. of B. & S. taper hole in spindle	10	10	10	11
Diameter of hole in spindle	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$
Speeds of countershaft	80 & 150	90 & 150	90 & 150	90 & 150
Size of countershaft pulleys	3x12″	3x12″	3½x12″	3½x12″
Floor space	69x58″	69x58″	82x68″	98½x72″
Dimensions of box for export	56x37x62	56x37x62	63x46x62	66x50x66
Index centers swing	10″	10″	10″	12″
Index centers take in length	15″	15″	17″	21″

PLAIN MILLING MACHINES.

The Plain Machines are built the same in size as the Universal Machines of corresponding numbers. They have all the movements of Universal Machines, with the exception that the table of a Plain Machine has no swivel movement, which is necessary in cutting spirals.

It is often thought that the swiveling of the table produces angular work, such as long key-shaped pieces or similar work. This, of course, is a mistaken idea.

The Plain Machines are simpler in construction and are built for more severe and heavier duty than the Universal Machines.

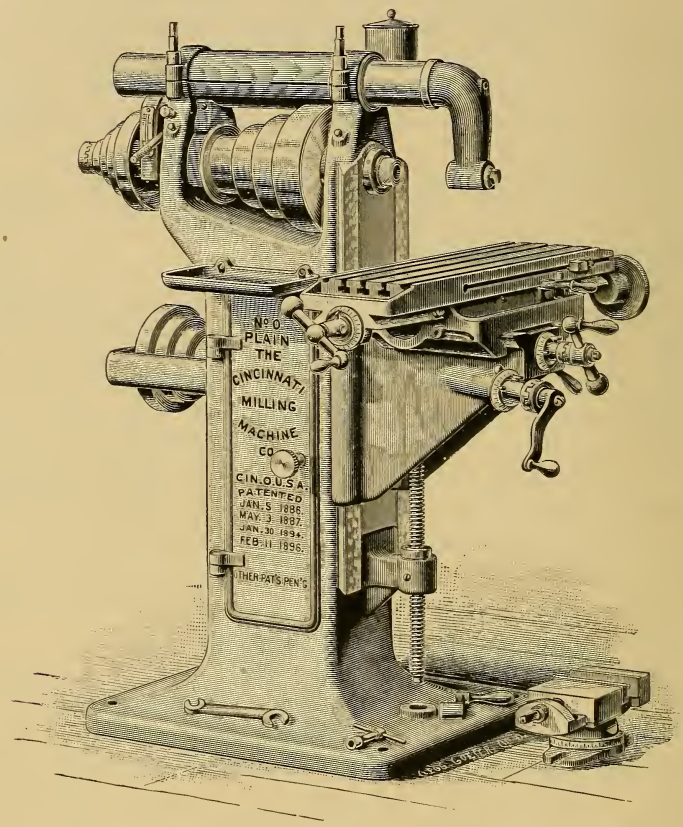
The table is fitted directly into the saddle which slides on the knee, and is larger on the Plain than on the Universal Machine.

All Plain Machines, except No. 0, are furnished with strong braces combining the knee and the overhanging arm very rigidly. These can be taken off very quickly when not required, by unscrewing the nut on the outer end of stud and releasing the clamp screw on the bridle which straddles the knee.

A number of these machines can be operated at the same time by a workman of limited skill, as the operations are usually very simple on work produced in large quantities.

Owing to their simplicity and greater capacity for turning out work, this type of machines is to be preferred for manufacturing purposes, and is best adapted for the majority of shops. In connection with the universal head and other attachments, every operation, except cutting of spirals, worm wheels or any other work requiring the swivel movement of the table, can be performed on these machines.

Table Feed,	.	18 in.
Cross "	.	5½ in.
Vertical "	.	14 in.



No. 0 Plain Milling Machine.

FIG. 15.

No. 0 PLAIN.

This machine is well adaped for light rapid milling, such as the manufacture of bicycle parts, electrical fittings and appliances, typewriters, etc.

The Spindle is bored to receive a No. 9 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{11}{16}$″ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 2½″ belt. The largest diameter is 10 inches.

The Overhanging Arm is 3¼″ diameter. It can be turned up out of the way, or it can be put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is 5⅛ inches.

The Table over all including oil pockets is 32½″ x 8″. The working surface is 27½″ x 8″. There are 3 T-slots ⅝″ wide. The top of the table can be lowered 14″ below the center of the spindle.

The Feed of the table is automatic in either direction through 18″. This feed is reversed by a lever on the front of the machine, without crossing the feed belt. The cross motion in line with the spindle is 5½″. There are 8 changes of feed which vary from .005″ to .100″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch.

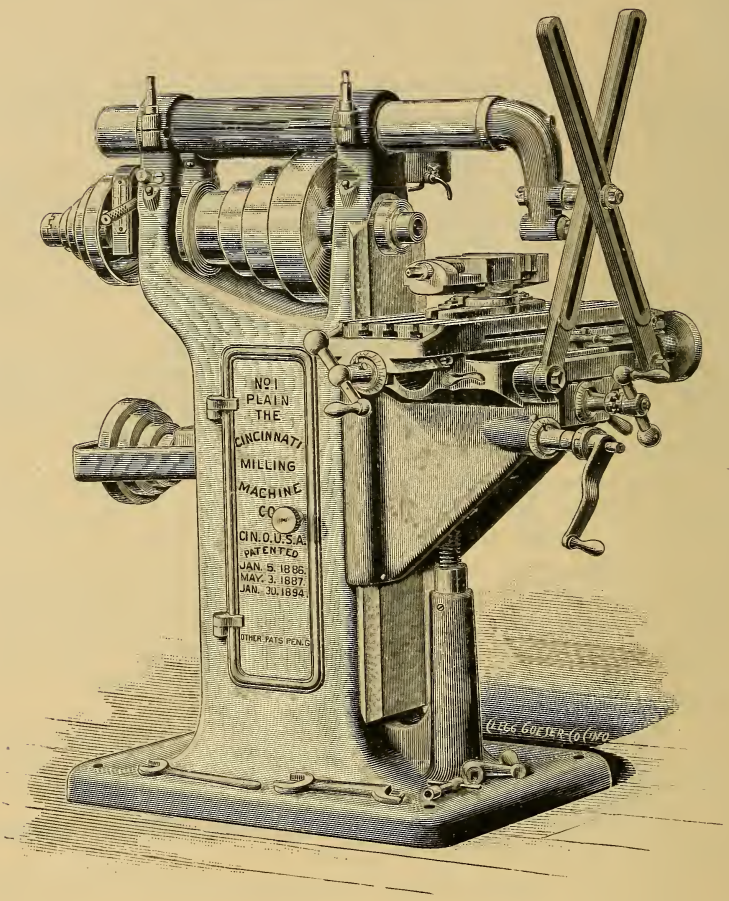
The Vise can be swiveled to any position, the angle of which is shown by the graduated base. The jaws are 6″ wide, $1\frac{7}{16}$″ deep, and will open 3½″.

The Countershaft has one 12-inch friction pulley for a 3″ belt which should run at 130 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 70″ x 51″.

Net Weight is 1280 pounds.

Table Feed, . 21 in.
Cross " . 6 in.
Vertical " . 19 in.



No. 1 Plain Milling Machine.

FIG. 16.

No. 1 PLAIN.

The No. 1 Plain is very convenient in model shops. It is well suited for manufacturing small articles, such as gun parts, sewing machine parts, etc.

The Spindle is bored to receive a No. 10 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{13}{16}$″ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 3″ belt. The largest diameter is 12 inches.

The Overhanging Arm is $3\frac{3}{4}$″ diameter. It can be turned up out of the way, or it can be put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is $6\frac{1}{8}$ inches.

The Table over all including oil pockets is 36″ x 9″. The working surface is 30″ x 9″. There are 3 T-slots $\frac{5}{8}$″ wide. The top of the table can be lowered 19″ below the center of the spindle.

The Feed of the table is automatic in either direction through 21″. This feed is reversed by a lever on the front of the machine, without crossing the feed belt. The cross motion in line with the spindle is 6″. There are 8 changes of feed which vary from .005″ to 100″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch.

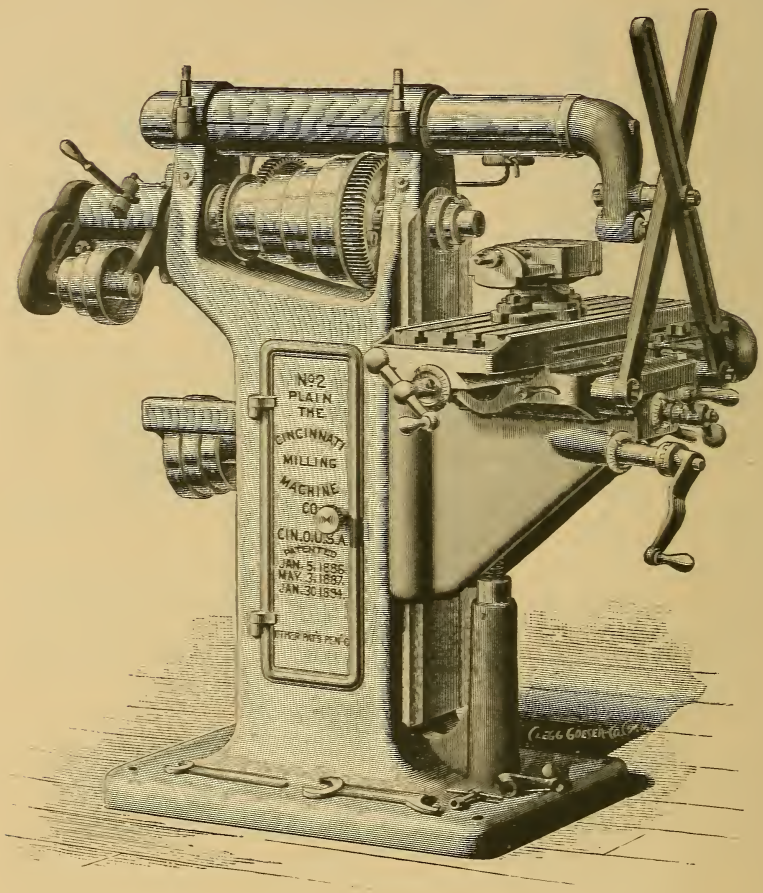
The Vise can be swiveled to any position, the angle of which is shown by the graduated base. The jaws are 6″ wide, $1\frac{7}{16}$″ deep, and will open $3\frac{1}{2}$″.

The Countershaft has two 12-inch friction pulleys for 3″ belts, which should run at 80 and 110 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 76 x 61 inches.

Net Weight is 1800 pounds.

Table Feed,	.	24 in.
Cross "	.	7½ in.
Vertical "	.	19 in.



No. 2 Plain Milling Machine.

FIG. 17.

No. 2 PLAIN.

The No. 2 Plain is, without doubt, the best machine for machine tool builders. It takes in a great range of work, and in general jobbing shop operations, it has become a very important tool. This machine is back-geared.

The Spindle is bored to receive a No. 10 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{13}{16}$″ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a $2\frac{3}{4}$″ belt. The largest diameter is 10 inches.

The Overhanging Arm is 4″ diameter. It can be turned up out of the way or it can be put in from the rear of the machine to receive various attachments. It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is $5\frac{9}{16}$ inches.

The Table over all including oil pockets is 40⅝″ x 10″. The working surface is 34⅝″ x 10″. There are 3 T-slots ⅝″ wide. The top of the table can be lowered 19″ below the center of the spindle.

The Feed of the table is automatic in either direction through 24″. This feed is reversed by a lever on the front of the machine, without crossing the feed belt. The cross motion in line with the spindle is 7½″. There are 12 changes of feed which vary from .006″ to .187″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch. This machine can be furnished with automatic cross and vertical feeds to order.

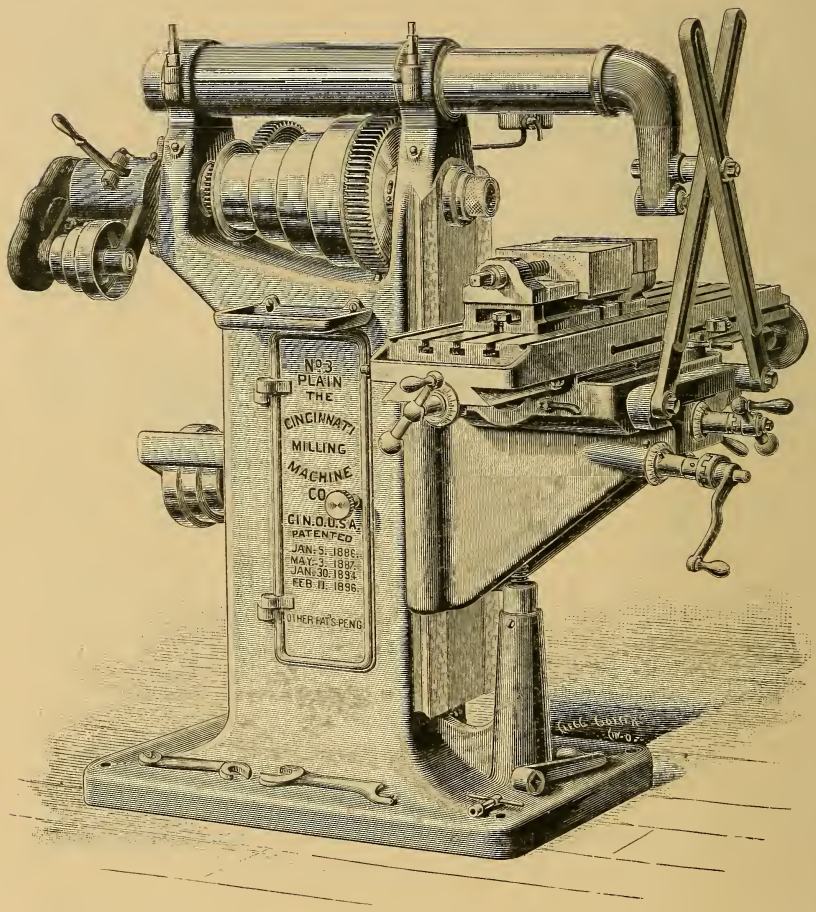
The Vise can be swiveled to any position the angle of which is shown by the graduated base. The jaws are 6″ wide, $1\frac{7}{16}$″ deep, and will open 3½″.

The Countershaft has two 12-inch friction pulleys for a 3½″ belt, which should run at 90 and 150 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 82″ x 68″.

Net Weight is 2100 pounds.

Table Feed,	.	32 in.
Cross "	.	9 in.
Vertical "	.	20 in.



No. 3 Plain Milling Machine.

FIG. 18.

No. 3 PLAIN.

The No. 3 Plain is designed for a heavier class of milling, and is well adapted for machine tool builders, engine and railroad shops, and large jobbing work. This machine is back-geared.

The Spindle is bored to receive a No. 11 B. & S. taper shank on cutter arbors and collets. From this taper bore, a hole $\frac{13}{16}$″ diameter is drilled through the remaining length of the spindle. The front end of the spindle is threaded and is provided with a guard-collar.

The Driving Cone has four steps for a 3″ belt. The largest diameter is 11½ inches.

The Overhanging Arm is 4½″ diameter. It can be turned up out of the way, or it can be put in from the rear of the machine to receive various attachments It is provided with an adjustable phosphor bronze bushing to support the cylindrical end of the arbor. The distance from center of spindle to overhanging arm is $6\frac{7}{16}$ inches.

The Table over all including oil pockets is 51″ x 12″. The working surface is 45″ x 12″. There are 3 T-slots ⅝″ wide. The top of the table can be lowered 20″ below the center of the spindle.

The Feed of the table is automatic in either direction through 32″. This feed is reversed by a lever on the front of the machine, without crossing the feed belt. The cross motion in line with the spindle is 9″. There are 12 changes of feed which vary from .006″ to .187″ travel of the table to one revolution of the cutter spindle. All feed adjustments are indicated by dials in thousandths of an inch. This machine can be furnished with automatic cross and vertical feeds to order.

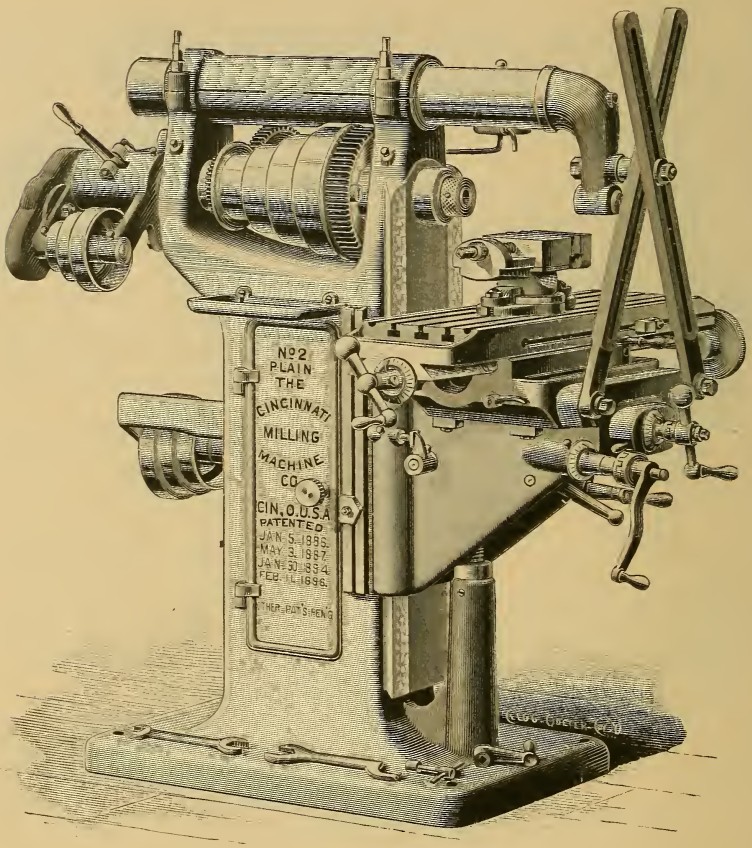
The Vise is flanged and can be clamped to the table with the jaws parallel to the table slots or at right angles to the table slots. The jaws are 8″ wide, 2⅜″ deep and will open 6″.

The Countershaft has two 12-inch friction pulleys for a 3½″ belt, which should run at 90 and 150 revolutions per minute.

The Floor Space necessary to permit the extreme limits of travel is 98½″ x 72″.

Net Weight is 2800 pounds.

Table Feed,	.	24 in.
Cross "	.	7½ in.
Vertical "	.	19 in.



No. 2 Plain Milling Machine.

Showing all Automatic Feeds.

FIG. 19.

GENERAL DIMENSIONS.

PLAIN MILLING MACHINES.

	Page 38	Page 40	Page 42	Page 44
	No. 0.	**No. 1.**	**No. 2.**	**No. 3.**
Net weight	1280 lbs.	1800 lbs.	2100 lbs.	2800 lbs.
Shipping weight about	1600 lbs.	2200 lbs.	2500 lbs.	3200 lbs.
Length of automatic feed to table	18″	21″	24″	32″
Cross motion in line with spindle	5½″	6″	7½″	9″
Vertical range	14″	19″	19″	20″
Size of table over all	32½x8″	36x9″	40⅝x10″	51x12″
Working surface of table	27½x8″	30x9″	34⅝x10″	45x12″
Largest diameter of driving pulley	10″	12″	10″	11½″
Number of steps on driving pulley	4	4	4	4
Number of spindle speeds	4	8	16	16
Width of driving belt	2½″	3″	2¾″	3″
Number of feed changes	8	8	12	12
Variations in feed to 1 rev. of spindle	.005 to .100	.005 to .100	.006 to .187	.006 to .187
Width of feed belt	1¼″	1¼″	1½″	1½″
Center of spindle to overhanging arm	5⅛″	6⅛″	$5\frac{9}{16}$″	$6\frac{7}{16}$″
Diameter of overhanging arm	3¼″	3¾″	4″	4½″
Back-geared	No.	No.	Yes.	Yes.
No. of vise furnished	1 Swiv.	1 Swiv.	1 Swiv.	3 Plain.
No. of B. & S. taper hole in spindle	9	10	10	11
Diameter of hole in spindle	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{13}{16}$
Speed of countershaft	130	80 & 150	90 & 150	90 & 150
Size of countershaft pulleys	3x12″	3x12″	3½x12″	3½x12″
Floor space	70x51″	76x61″	82x68″	98½x72″
Dimensions of box for export	51x45x57	58x50x62	63x54x62	66x64x66

ATTACHMENTS

FOR

MILLING MACHINES.

All attachments can be used on the machines interchangeably, the table-slots being finished to a standard gauge. Attention is called to this feature, as the machine can be ordered without attachments, and at any future time, these attachments can be supplied to fit any machine previously bought. When ordering, it is very necessary to specify the size of machine for which the attachment is wanted.

UNIVERSAL INDEXING AND DIVIDING HEAD.

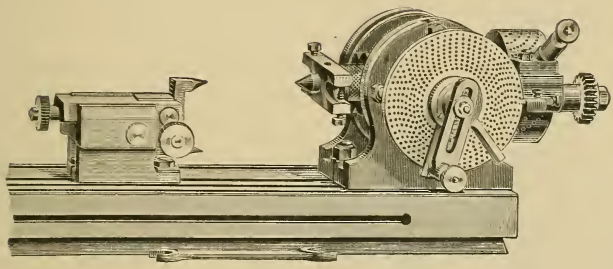


FIG. 20.

The above illustrates a new Universal Indexing and Dividing Head with Patent Back Center. A number of new features and improvements are embodied in this head which is very compact and rigid. It is distinctly universal, as swiveling block which carries spindle makes a complete revolution. This is an important feature and a great advantage on certain kinds of work. In starting a cutter on work held in a chuck or on mitre and bevel wheels, of small diameter especially such with long hubs or small holes, it has been a difficult matter to prevent gouging of the cutter. This trouble is overcome on this head by swinging the spindle over on the other side of the vertical line, the cut now being of a sweeping nature. With the work held in this position, heavier cuts can be taken, the feed may be faster, and a smoother finish will be obtained. Right and left hand work may be cut without changing the cutter.

The block carrying the spindle is always fully contained within its bearings, at whatever angle the spindle is held. A circular T slot, similar to that of a planer head, is turned in one side of the swiveling block. By means of two T bolts in this slot and an additional clamping device on the other side, the swivel block is firmly held in any position. This circular T slot is entirely concealed and can not become clogged with chips.

The spindle receives the same arbors as the main spindle of the milling machine, and it will take work through its entire length $1\frac{1}{16}$ inches diameter. The front end of spindle is threaded to receive a 6 inch universal chuck for all Universal machines except No. 3, which is fitted with a 9 inch chuck. When not in use, the thread is protected by a collar. The chuck fitting this spindle is also made to fit the main spindle of the machine. The spindle itself is provided with a clamping device by

means of which it can be firmly locked during cutting operation relieving the worm and worm wheel and index pointer of all strain, and thereby avoiding unnecessary wear.

The head is provided with two dividing mechanisms, viz., worm and worm wheel with side index-plate, and cup-shaped index plate without worm and worm wheel. The side index-plate is made of large diameter and sufficiently thick to have enough circles of holes drilled on its two surfaces for all division up to 360. This avoids the use of extra plates and frequent changing. For rapid indexing on such work as milling reamers, taps, nuts, etc., and cutting spur wheels with less than 40 teeth, the worm may be disengaged from worm wheel and cup-shaped index plate used. This is fastened by a nut directly on spindle and may be used on divisions of 3, 4, 6, 8, etc., to 38. In cutting a small number of divisions on other heads having only the worm mechanism for dividing, mistakes are frequently made in counting the number of turns of worm. This is overcome on this head as on all divisions of forty and above, more than one turn of the worm is never required.

The tail-stock has the patent adjustable center bar, which is raised and lowered by means of rack and pinion for taper work. The center bar has a small center on one end with top milled off, and a large center for heavy work on the other. The slide of tail-stock is adjusted by a screw for putting in and taking out work. There are two clamping bolts, one for locking center bar and the other for locking slide.

Eight *change gears* are furnished with Universal machines for cutting spirals, both right and left, automatically.

Two sizes of this head are made, one to swing 12 inches, another 10 inches. Raising blocks 2 inches and 4 inches thick, however, can be furnished to take in work 16 and 20 inches diameter on the 12 inch head and 14 and 18 inches diameter on the 10 inch head.

By means of the angle plate, the head can be set at any angle on the table.

Weight, 10 inch, 135 pounds; 12 inch, 208 pounds.

PLAIN INDEXING CENTERS.

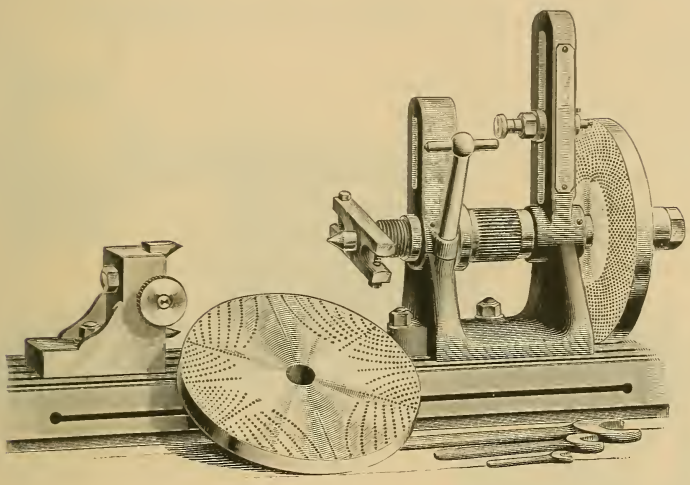


FIG. 21.

These Centers take in work 12 inches in diameter and are intended for use in shops where spirals and bevel gears are not required to be cut. Raising blocks 2 inches and 4 inches thick can be furnished to take in work of 16 and 20 inches diameter. The spindle is threaded and in the front end has No. 10 Brown & Sharpe taper hole, with a ¾ straight hole extending through. The spindle is firmly locked in position by the clamping screw shown, thereby avoiding unnecessary strain and wear on index pin and index plate. Two plates are regularly furnished for making divisions up to 100. Special plates furnished to order. The tail-stock has the patent adjustable center bar, on one end is a full round center and on the other a center with the top milled off. The center bar is raised or lowered for taper work by means of a rack and pinion.

A lateral adjustment for spindle is provided for taking out work.

Weight, 128 pounds.

RACK CUTTING ATTACHMENT.

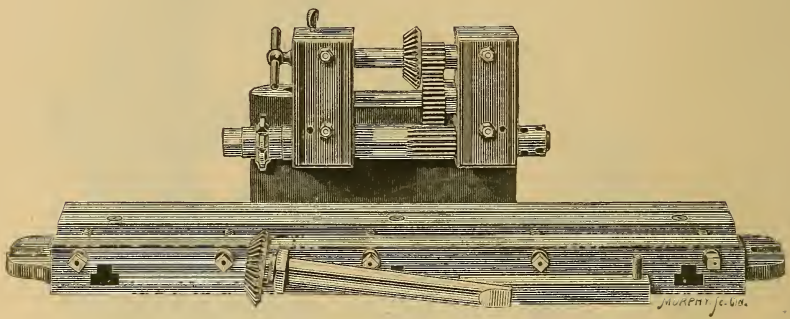


FIG. 22.

This attachment is constructed to revolve the milling cutter transversely to main spindle of machine, permitting racks of any length to be cut. It can also be used to an advantage for cutting off stock. Two sizes are made. No. 1 is adapted to Nos. 1, 2 and 3 Plain and Nos. 1, 1½, 2 and 3 Universal machines, and will cut racks up to 6 pitch 2 inches wide, using standard size cutters. A vise 30 inches long for holding work is furnished with this attachment.

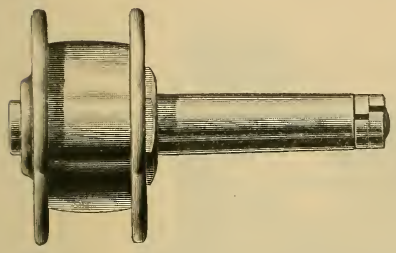
In ordering, the size of the machine must be given for which the attachment is wanted.

No. 2 is made only for No. 3 Plain and No. 3 Universal machines and with special cutters of large diameter, racks up to 3 pitch can be cut. The vise for this size will work 34 inches long and 5⅜ inches wide.

Weight, No. 1, 175 pounds; No 2, 400 pounds.

HIGH SPEED MILLING ATTACHMENT.

For Nos. 1, 1½, 2 and 3 Universal and Nos. 1, 2 and 3 Plain Milling Machines.



This attachment is advantageously used for light milling with small end mills. The spindle has a No. 4 Brown & Sharpe taper hole and runs in a Phosphor Bronze shell that fits the taper hole in main spindle. The above attachment is driven by means of two pulleys mounted on a bracket, which is clamped in position on the end of overhanging arm. This method allows the use of power feeds; also of cone driving pulley in the usual manner and provides a large number of speeds for the end mill.

On the No. 1 Universal and No. 1 Plain machines there are eight changes of speed, from 284 to 1564 revolutions per minute. On the Nos. 1½ and 2 Universal and No. 2 Plain milling machines there are eight changes of speed from 388 to 1578 revolutions per minute.

In ordering, the size of the machine must be given for which the attachment is wanted.

Weight, 55 pounds.

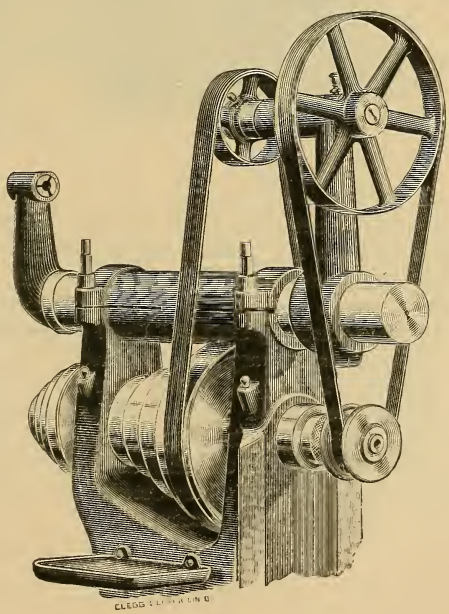


FIG. 23.

VERTICAL SPINDLE MILLING ATTACHMENT.

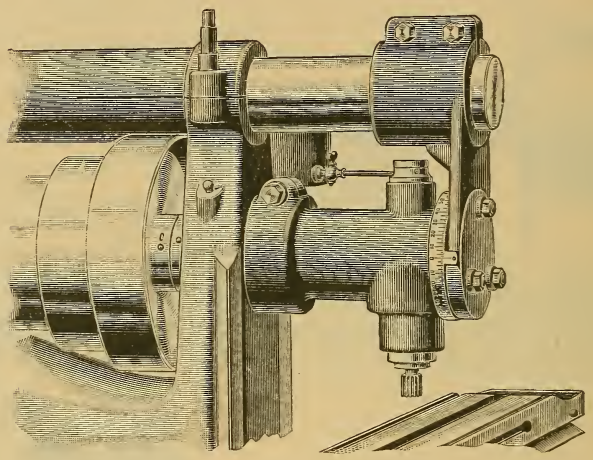


FIG. 24.

This attachment can be advantageously used on various kinds of work, such as key seating, die-sinking, cutting T slots and work which can not be conveniently or properly held to use a horizontal milling cutter. It is well braced and rigidly held in position. The vertical spindle is driven by means of bevel gears and shaft in main spindle. It can be set at any angle, a graduated index being provided. The No. 1 attachment is adapted to Nos. 1, 2 and 3 Plain and Nos. 1, 1½, 2 and 3 Universal machines. Distance from center of spindle to face of column 8 inches. Hole in spindle No. 7 Brown & Sharpe taper. An "A" Collet is furnished with the attachment. In ordering, the size of the machine must be given for which the attachment is wanted.

Weight, about 72 pounds.

CAM CUTTING ATTACHMENT.

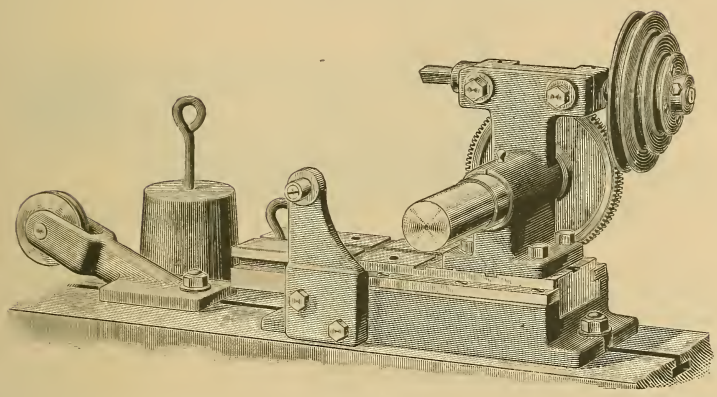


FIG. 25.

Face and cylindrical cams can be cut with the Cam Cutting attachment. The change from face to cylindrical cam cutting is readily made by turning the worm wheel spindle at right angles to milling machine spindle. The bolt holes in the slide and in the spindle housing being jig drilled allow this change to be made quickly.

The worm gear is large in diameter. Provision is made for taking up the end play of the worm and also any looseness between the worm and worm wheel.

The spindle can be turned either by hand or by power. Cam cutting can now be done on a milling machine as well as on a special machine built for this purpose.

Weight, 259 pounds.

CAM CUTTING ATTACHMENT.

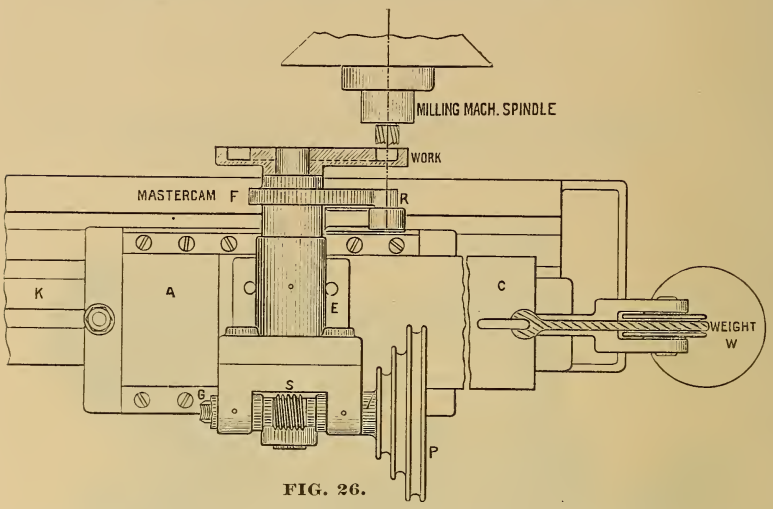


FIG. 26.

The Cam Cutting Attachment applied to the cutting of a face cam is shown in Fig. 26. The device consists of a sliding head-stock E, and a base-plate A, which is fastened to the table K of the milling machine.

Within the head-stock E, there is a spindle which may be driven through worm S and worm gear G, by a belt running on pulley P.

An extension of the worm-shaft (not shown in cut) is milled to receive a crank for hand feeding and adjusting work. The power feed should be used wherever possible, as its regularity of motion overcomes the resistance of any irregularities due to the form of the cam.

The worm gearing is large and powerful. Provision is made for taking up the end play of the worm, and also any looseness between the worm and worm-wheel.

On the spindle of this device is attached a master cam F, which engages with the roller R, located on a bracket rigidly attached to the base plate A. The sliding plate C, is held in working engagement with this roller by the heavy weight W. In this way, the work is so fed to the cutter as to prodnce a true counterpart of the master cam.

When cutting cylindrical cams, the axis of the work has to be set in line parallel with the slide plate A. The cutting of cams with this device in connection with the milling machine is performed as perfectly as upon an expensive machine, expressly built for such work.

When cams are cut out of the solid stock, a roughing cutter should be used first; this cutter is usually $\frac{1}{16}$ of an inch less in diameter than the finishing cutter, which must have the same diameter as that of the roller intended to work in this cam.

Where the master cam is of exact size as the cam to be cut, the master roller R must be the same diameter as the finishing cutter and the axis of the roller must be in line with the axis of the cutter, but where the master cam is of larger diameter than the cam to be cut, the roller R must be increased in diameter correspondingly; that is to say, the ratio of the diameter of the roller to the diameter of the finishing cutter must equal the ratio of the greatest throw of the master cam to the greatest throw of the cam to be cut. In the latter case, the roller and the finishing cutter are no longer in line on account of the size of the master cam. The roller must be moved from its position opposite the cutter far enough to give room for the master cam.

ROTARY MILLING ATTACHMENT.

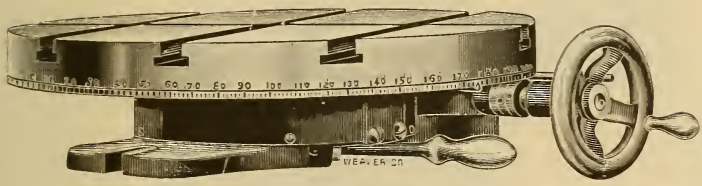


FIG. 27.

This attachment is well adapted for milling circles, segments of circles, circular slots, etc., and circular surfaces, especially those which end abrubtly or merge into straight surfaces are also easily milled. It is used with the vertical spindle milling attachment to good advantage, and may be attached to any machine.

The milling machine table to which the attachment is bolted is held stationary when circular milling is being done. When bolted to the milling machine table, the circular table of the attachment can be turned to any required position. The circular table can be turned by hand or automatically. The table is 15 inches in diameter and has 4 T-slots $\frac{5}{8}''$ wide, finished to the same gauge as the milling machine table-slots. The attachment is $3\frac{3}{4}$ inches high.

Weight, 80 pounds.

VISES.

Vise shown in Fig. 28 swivels, has a graduated base and ends of jaws open for better clamping long work in an upright position. The base is provided with tongues which fit T-slot in table. The jaws are made of steel. The No. 1 Swivel Vise is furnished with Nos. 0, 1 and 2 Plain and Nos. 1, 1½ and 2 Universal and the No. 2 with No. 3 Universal Milling Machines. The plain Vise shown in Fig. 29 is flanged for clamping. It may be held parallel or right angular to table as tongues are detachable. The No. 1 may be used with Nos. 0, 1 and 2 Plain or Universal Machines. The No. 3 is regularly furnished with the No. 3 Plain Milling Machines.

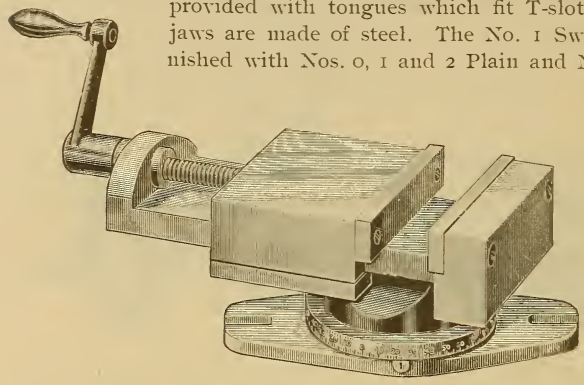


FIG. 28.

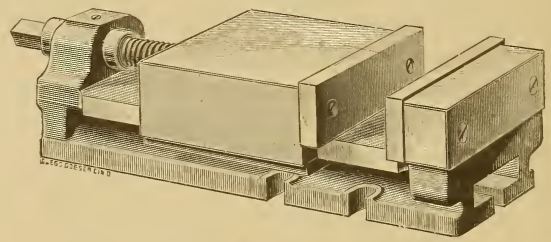


FIG. 29.

DIMENSIONS.

SWIVEL.					PLAIN.				
Size.	Depth of Jaws	Width of Jaws	Jaws Open.	Weight.	Size.	Depth of Jaws	Width of Jaws	Jaws Open.	Weight.
1	1 7/16	6″	3½″	50	1	1 7/16	6″	3½″	35
2	1 7/16	7″	4¼″	75	3	2⅜	8″	6 ″	90

ARBORS FOR MILLING MACHINES.

We carry in stock Arbors as listed below. The large hexagon nut shown at E, Fig. 30, is used for backing out Arbor, by forcing this nut against the end of spindle.

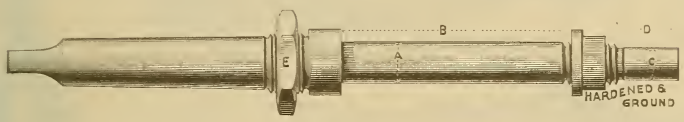


FIG. 30.

No.	Diameter A	Length B from Shoulder to Nut.	No. Machine Where Used.	No. of Taper.
04	½″	1½″	Nos. 0, 1 and 2 Plain and 1, 1½ and 2 Universal.	7
07	⅝″	4″	No. 0 Plain.	9
08	⅞″	5″		9
09	1″	6″		9
1	⅝″	4″	No. 1, 1½ and 2 Universal and Nos. 1 and 2 Plain.	10
2	⅞″	4″		10
3	1″	4″		10
4	1 1/16″	4″		10
5	1¼″	4″		10
6	⅞″	6″		10
7	1″	6″		10
8	1 1/16″	6″		10
9	1¼″	6″		10
10	⅞″	8″		10
11	1″	8″		10
12	1 1/16″	8″		10
13	1¼″	8″		10
15	⅞″	8″	No. 3 Universal and No. 3 Plain.	11
16	1″	8″		11
17	1 1/16″	10″		11
18	1¼″	10″		11

A NEW MILLING MACHINE DOG.

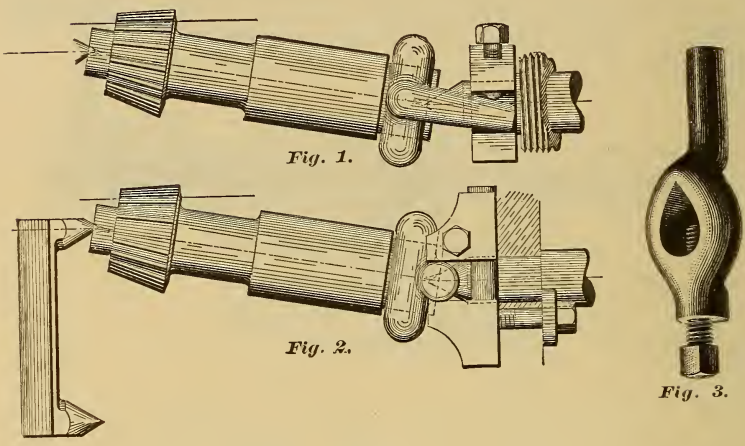


FIG. 31.

Often taper work is done on a milling machine between centers, and an ordinary dog with a bent taper tail is used for carrying the article to be milled. Referring to Fig. 1, it will be noticed that the action which takes place by revolving the work is a continuous gaining and losing one. This is due to the fact that the bent tail continuously changes its position at the point of driving. It can readily be seen that it twists right and left, and at the same time slides forward and back as the dog changes from the vertical to horizontal position in turning over. Now if the set screw which holds the tail to the dog carrier is not released for every partial revolution, the tendency is to either spring or bend light work, or it will throw an enormous strain between centers on heavy work, so that it is almost impossible to revolve it, causing uneven divisions. Figs. 2 and 3 represent a milling machine dog in which the above defects are overcome. The tail of the same is turned cylindrical, and is offset, so that the center line through the cylindrical part is in line with the end of the work when the dog is set flush. In addition to the dog there is an adjustable clamp attached

to the regular dog driver, which firmly holds any size dog and at the same time admits the tail to swivel either way or slide forward and backward. With a dog and clamp of this design, taper or straight work may be revolved between centers and held firmly in any position without any strain whatever. The same arrangement can be used on lathe work, and it is especially advantageous for thread cutting, for two reasons. First, where taper threads are cut between centers with the old style dog, the action of losing and gaining on the thread takes place the same as in the milling machine work, and produces what is called a drunken thread; by using the improved dog this trouble is entirely avoided. Second, there is no back lash in reversing the lathe, and a dog of this pattern is always on time.

All sizes from ¼″ to 2½″ are made and furnished with a well-finished tool steel screw (threaded in the lathe) with a tempered point.

Sizes made are ¼″, ⅜″, ½″, ⅝″, ¾″, 1″, 1¼″, 1½″, 2″ and 2½″.

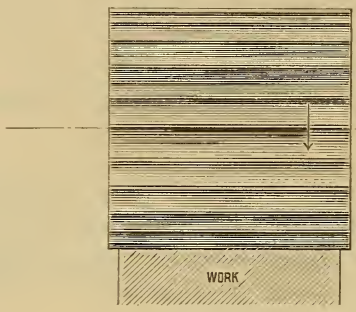


FIG. 32.

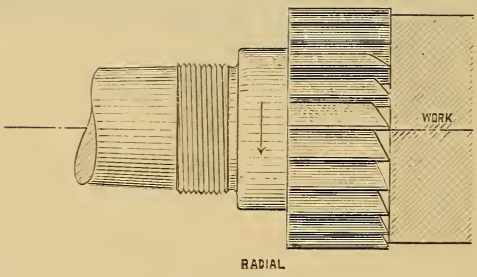


FIG. 33.

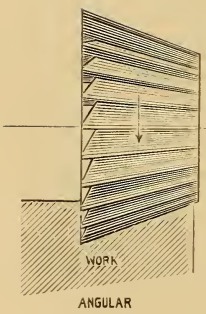


FIG. 34.

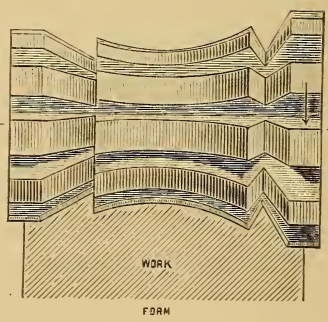


FIG. 35.

CUTTERS.

Milling Cutters may be classified in four distinct types. The first and probably the most common form is known as the axial, Fig. 32, in which the surface cut is parallel to the axis of the cutter. This cutter has teeth on its periphery only; these may be straight or spiral teeth. Cutters of this character, made in appropriate widths, are used very much for milling broad flat surfaces, and for cutting key-ways in shafts. For deep cuts, or for slitting metal, they are made of large diameter and thin. These are called metal slitting saws and are ground hollow on the sides for clearance.

The second class of cutters is known as the radial, Fig. 33, in which the surface cut is perpendicular to the axis of the cutter. These cutters are called radial because their teeth are used in a plane parallel to the radii of the cutter. End mills, face mills, butt cutters, etc., are all tools in this class.

The third class of cutters is the angular, Fig. 34, in which the surface cut is neither parallel nor perpendicular to the axis of the cutter, but is at some angle with this axis. Frequently, cutters are made with two different angular cutting edges, in which case the angle is marked on each side.

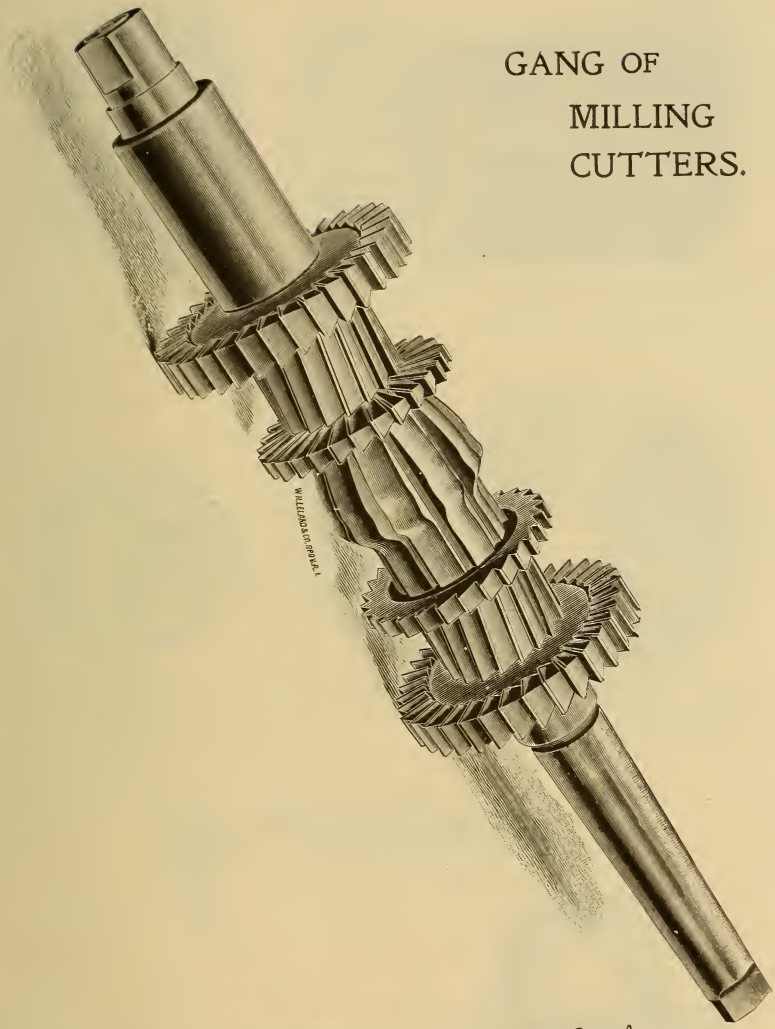
The fourth class of cutters is the form cutter, as shown in Fig. 35. The cutting edge in this class is of an irregular outline. When properly backed off, these cutters can be ground

and retain their original form. Gear cutters, tools for grooving taps, etc., are all classed as form cutters.

Fig. 36 shows an inexpensive method of attaching the tool-steel cutter, A, to the taper shank, B, which may be made of a cheaper grade of steel. A rod can be screwed into the tapped hole C from the back end of the spindle to hold the taper shank tight in the spindle.

The three following pages illustrate a number of cutters which are used on milling machines. In most cases, it is advisable to use a cutter of small diameter rather than of large diameter. Cutters from 1½ to 2 inches in diameter are the most economical for general milling.

GANG OF MILLING CUTTERS.



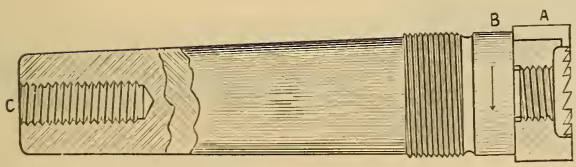
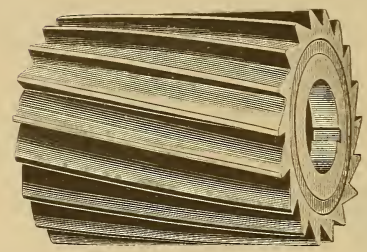
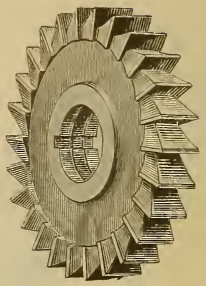


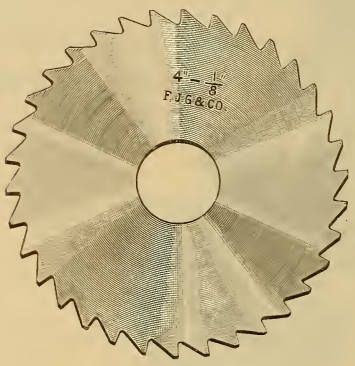
FIG. 36.



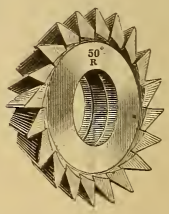
GENERAL FLAT SURFACE MILLING.



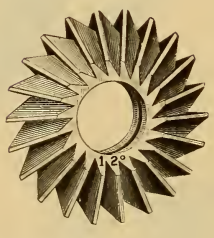
FOR KEY-SEATS, SLOTS, AND STRADDLE MILLING WHEN USED IN PAIRS.



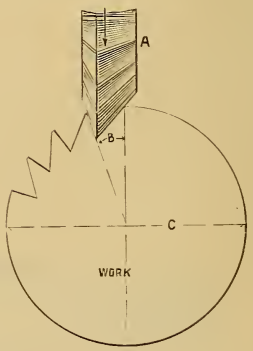
FOR SAWING AND SLITTING.



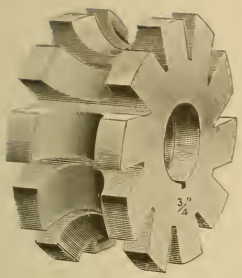
RIGHT-HAND CUTTER.
FOR RATCHET TEETH, TEETH IN MILLING CUTTERS.



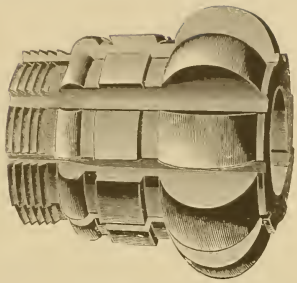
RIGHT-HAND CUTTER.
FOR CUTTING TEETH IN SPIRAL MILLING CUTTERS.



HOW TO ADJUST CUTTER TO WORK FOR CUTTING SPIRALS.

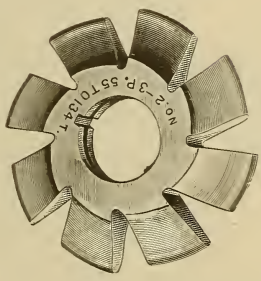


CONCAVE AND CONVEX CUTTERS FOR MILLING HALF CIRCLES.

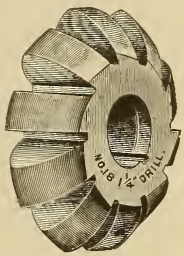


FORMED MILLING CUTTER FOR MILLING PARTS OF MACHINERY.

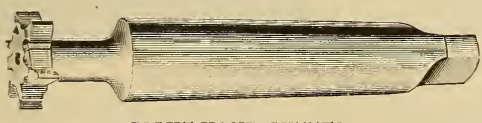
FOR TAPS AND REAMERS.



FOR TEETH IN GEAR-WHEELS.

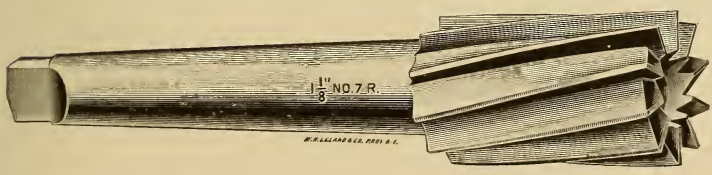


FOR GROOVING STRAIGHT-LIPPED TWIST-DRILLS.

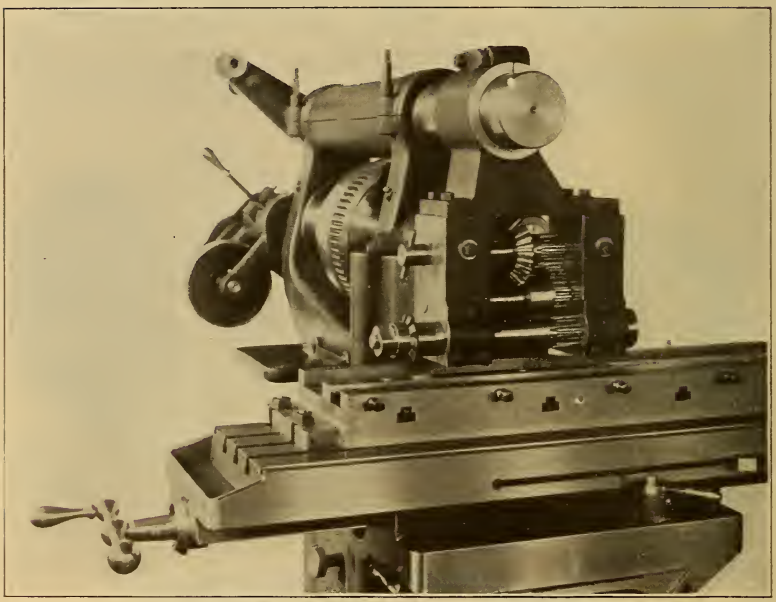


RIGHT-HAND CUTTER.

T-SLOT CUTTER.



FOR END-MILLING, DIE-SINKING, AND MILLING SLOTS.



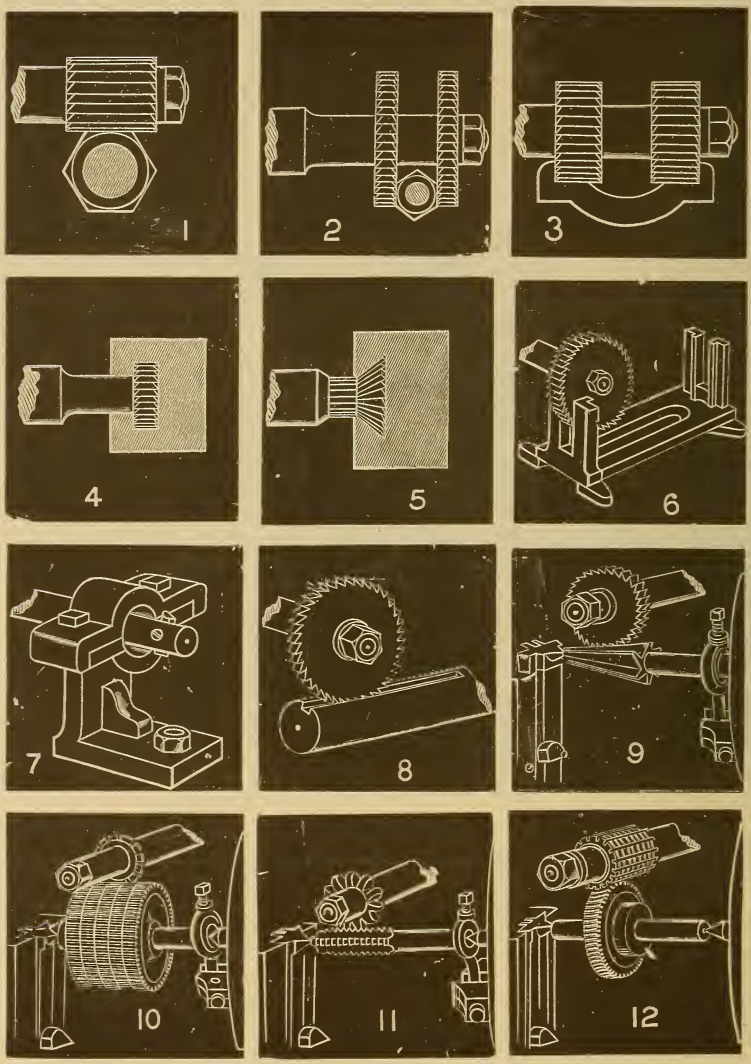
RACK CUTTING ATTACHMENT AND VISE.

(See Page 52).

EXAMPLES

OF

MILLING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EXPLANATION OF CUTS ON OPPOSITE PAGE.

Figure 1. Illustrates milling hexagon nuts or heads of bolts with a single cutter.

Fig. 2. How a number of nuts, strung on a mandrel, may be milled at the same time with two cutters.

Fig. 3. How to mill a lot of caps, accurately finishing the sides and bottom at the same time.

Fig. 4. How to mill a T slot having the groove milled to proper depth.

Fig. 5. How to mill a V slot.

Fig. 6. How to mill the guides of a housing. This can be done with a cutter the width of guide, or with a saw about $\frac{1}{4}$-inch thick, finishing one side and then the other. A small cutter should then be applied to finish inside bearings. The housing requires but one chucking.

Fig. 7. How to turn out a hole with a boring bar arbor. Various work can be drilled and bored out to advantage in this way, by either bolting the work on the table, holding it in a vise or between centers.

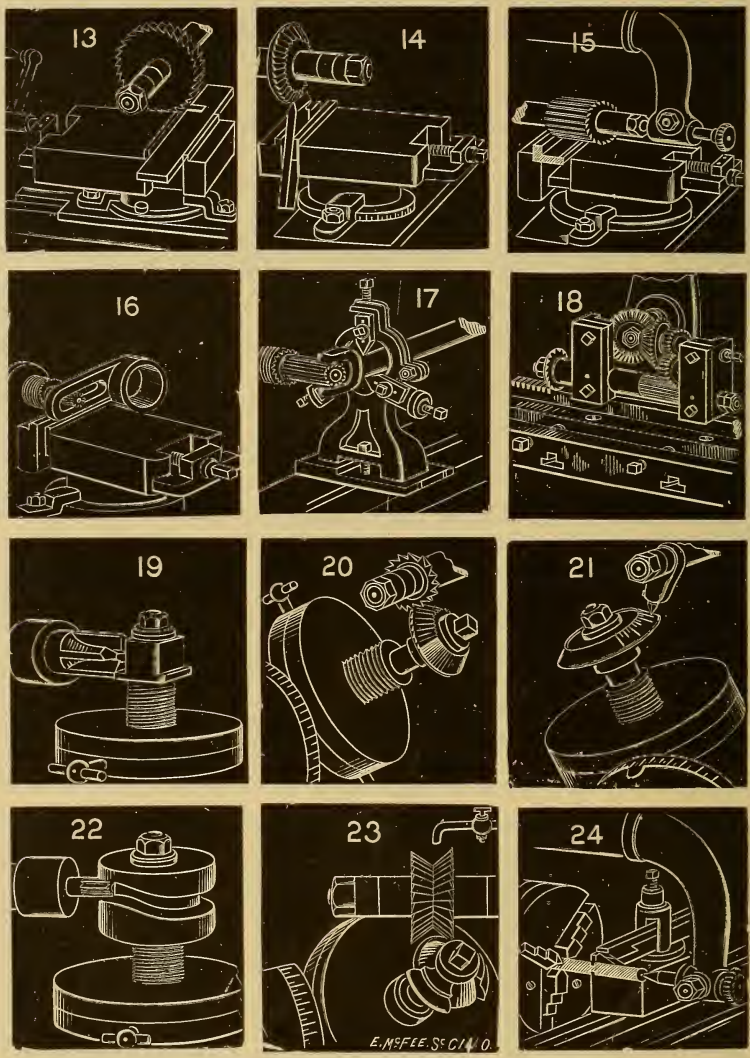
Fig. 8. How to mill a key seat. This may be done holding the shaft in a vise or between centers.

Fig. 9. How to mill a taper reamer with center bar in tail stock elevated.

Fig. 10. How to cut a number of gear wheels when strung on a mandrel.

Fig. 11. How to mill a tap.

Fig. 12. How to hob a worm wheel after the teeth are cut. This operation gives the teeth the proper shape, so that the shafts will work at right angles to each other.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EXPLANATION OF CUTS ON OPPOSITE PAGE.

Fig. 13. How to cut off pieces of metal.

Fig. 14. How to mill a thread chasing tool. The milling cutter is to be V shaped and 60 degrees. Mill one side first, and then the other, without re-chucking.

Fig. 15. How to mill an angle, finishing sides and bottoms at the same time.

Fig. 16. How to mill a slot with a small cutter.

Fig. 17. How to mill a fork true with its round shank. One end is held in a universal chuck, which is screwed on the spindle of the indexing center, and the other held in a steady rest.

Fig. 18. How to cut a rack.

Fig. 19. How to mill boxes perfectly true with the hole.

Fig. 20. How to mill an angular cutter.

Fig. 21. How to index dial plates. In this case the tool does not revolve.

Fig. 22. How to mill a cam.

Fig. 23. How to mill a friezing bit for wood work. First, the sections are milled out with a square faced cutter, and then the cutting edges are milled by placing a right and left angular cutter on the milling arbor. These bits can be milled complete before removing them from the mandrel.

Fig. 24. How to cut off round or square stock, by placing the universal chuck on the main spindle, and using the overhanging arm for a length gauge.

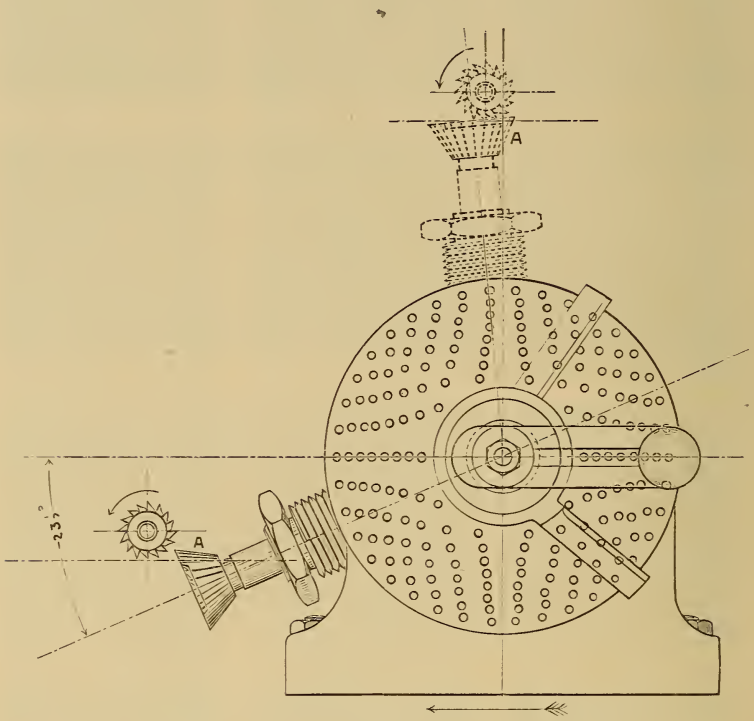

FIG. 37.

EXAMPLES OF MILLING.

Fig. 37 shows how the two cutting edges of the angular milling cutter A, may be cut without removing the work from the spindle. In the position shown in full lines, the dividing head spindle is set below the horizontal 23½ degrees, which allows a horizontal instead of a vertical cut to be taken.

A vertical cut would be necessary if the spindle could not be deflected as shown. The dotted lines indicate the position necessary for milling the end teeth.

In setting the dividing head spindle from one angle to another, the spindle is slightly revolved on its axis due to the action of the worm on the worm wheel. Therefore, before cutting the end teeth, revolve the dividing head spindle slightly by moving the index pin one or more holes forward or backward, as the case may require.

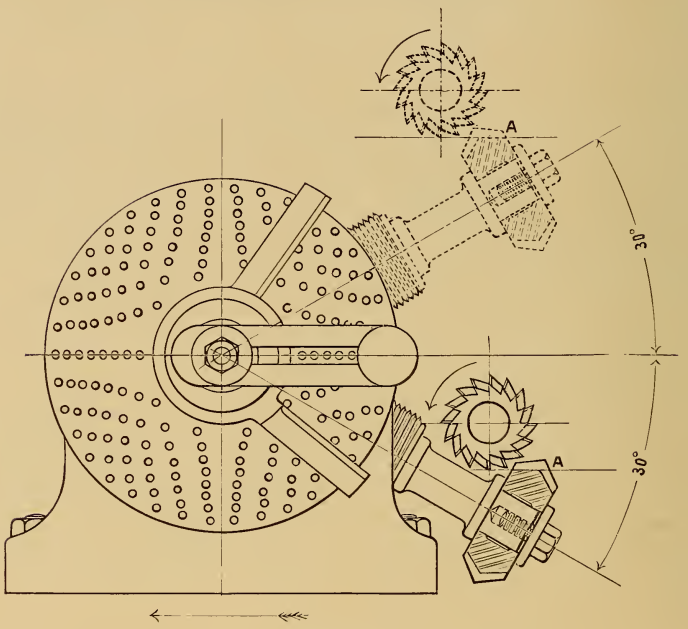

FIG. 38.

EXAMPLES OF MILLING.

Cutting Double-Angle Milling Cutter.

Fig. 38 shows the manner of cutting teeth in a double angular milling cutter A, without reversing the angular cutter on the main spindle or taking the work off the mandrel. The angular cutter, on the main spindle, runs only in the right hand direction. The double angular cutter blank A, on the work spindle is elevated to the required angle on the right side of the head, in order that the cut may be of a sweeping nature and to prevent the cutter from gouging into the work.

To cut the teeth on the other angle of the cutter, the dividing head spindle is swiveled 30 degrees below the horizontal line. This completes all the operations without removing either the work A or the cutter.

These operations could be performed with the work on the left side instead of on the right side of the dividing head, and without removing the work or changing the cutter ; but the direction of the cut would have a tendency to drag the work deeper into the cutter and spoil it.

Similar work can be done in the same manner by setting the dividing head spindle to the required angle to the right and left of its vertical position. It may be convenient in such a case to use the automatic vertical feed, which should always be in a direction to allow the cutter to push the work away from it.

EXAMPLES OF MILLING.

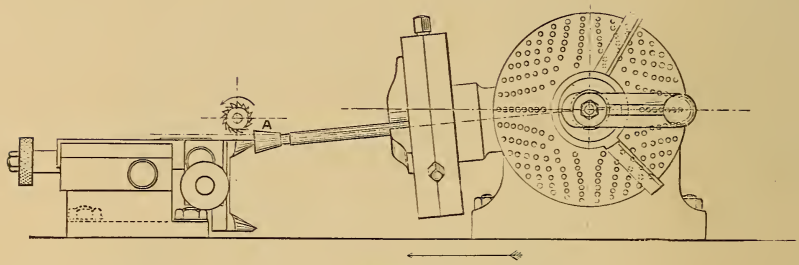

FIG. 39.

Fig. 39 shows the use of the adjustable center bar in a lowered position for supporting the end of the cutter A, and similar work. This affords the advantage of a free passage of the cutter over the tail-stock.

EXAMPLES OF MILLING.

The facility with which the table and its swiveling carriage can be turned to any degree of angularity with respect to the cutter spindle, offers some important advantages.

One example is illustrated in Figs. 40, 41 and 42, which shows the facility with which this job has its opposite sides milled parallel. These illustrations also show the manner of milling the three T-slots in the work without re-chucking it.

The piece is clamped with the finished surface A, on the table K. In Fig. 40, the table K is shown in its ordinary position.

In this position, one cut across the work with the face mill, will finish the surface B. Then the swiveling carriage J, and the table K, with the work can be turned through 180 degrees, or half way around, as shown in Fig. 41. in which position the face C is milled. The two faces B and C, will become true and perfectly parallel to each other and perpendicular to the base surface A.

Turning the table half way around does not in any way interfere with the automatic operation of the feed and the hand lever.

After milling the faces B and C, the three T-slots can be milled parallel and in their proper location without re-chucking the work. In Fig. 42, the operations of the end mill F and

the T-slot cutter G are shown. Slots of suitable depth and proper width are first milled in the face C, with the cutter F in either one or two cuts, according to the accuracy required. A similar slot is cut in face B, after the table is revolved. Then the head of the T-slot in the side B, is milled with the cutter G, after which the table is revolved and the T-slots are finished in the face C, with the same cutter G.

It will be observed that the table has been swiveled three times to complete the eight operations on the two sides without re-chucking the work. On such work where the chucking is complicated, this feature is of a decided advantage.

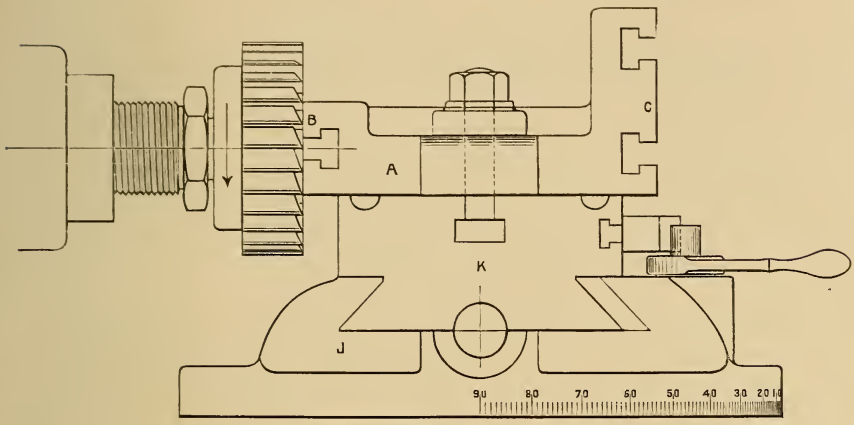

FIG. 40.

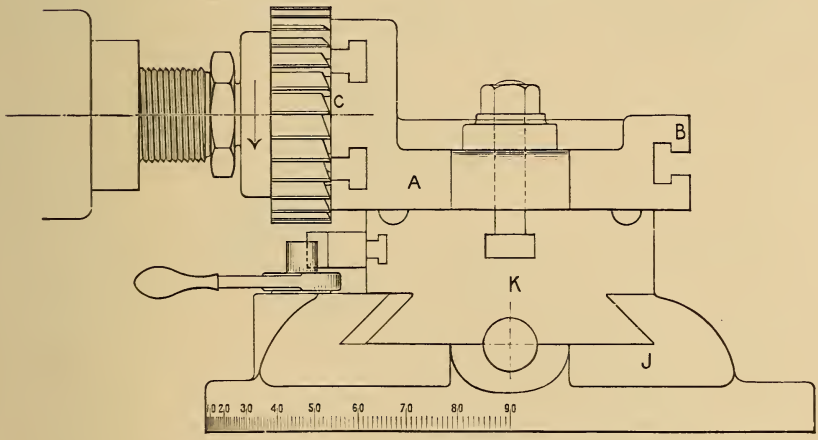

FIG. 41.

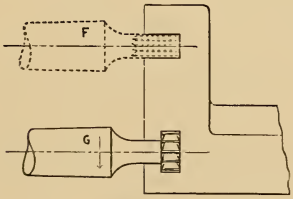

FIG. 42.

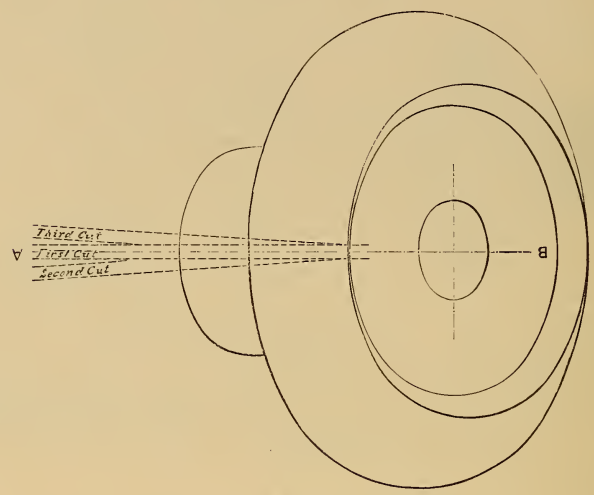

FIG. 43.

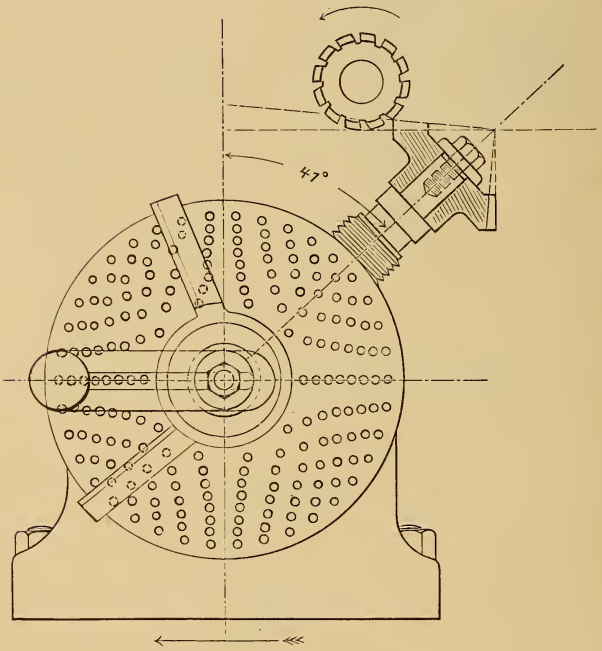

FIG. 44.

CUTTING BEVEL AND MITER WHEELS.

In cutting bevel and miter gear wheels on a Universal Milling Machine, the swivel housing is set at zero and is not swiveled for any operation.

Cutting Operations.

First adjust the work so that the center line A B, Fig. 43, of the wheel to be cut coincides with the center line of cutter, and cut two or three teeth of the proper depth.

For the succeeding operations which are explained in the example given below, no fixed rule can be given as wheels of different diameters, faces, and pitches require different settings.

The following miter wheel has been taken as an example.

12 Pitch.
32 Teeth.
$3\frac{2}{1}\frac{}{2}''$ Pitch Diameter.
$2\frac{1}{1}\frac{3}{6}''$ Outside Diameter.
$\frac{7}{1}\frac{}{2}''$ Face.

The index chart which is furnished with every dividing head shows that for cutting 32 teeth, the 28 hole index circle should be used, and to advance one revolution and 7 holes for every succeeding tooth. After the first two or three teeth have been cut, proceed to take second cut, Fig. 43, after slightly revolving the miter wheel by advancing the index pointer five holes, and also shifting the wheel twenty thousandths out of center by moving the cross slide this amount out from the column. After this cut has been taken, proceed to third cut as follows: turn the index pointer back ten holes and move cross slide back towards column forty thousandths.

These operations completed will produce a tooth of the proper form, and the remaining teeth can be cut by simply using the second and third operations. These figures are correct only for the above wheel and will vary with each wheel.

The cutter, if properly made, will leave the small end of the

tooth of the proper thickness, and care must be taken in the second and third operations that the cutter does not make the space already cut wider on the small end of the tooth.

If wheels must be duplicated, it is advisable to note figures for future reference. For the proper thickness of the tooth on the large pitch diameter, see table, page 122.

It is best to set the pointers at zero on the cross slide and vertical slide after the machine has been adjusted for these operations. The depth of the teeth in miter and bevel wheels should be measured at the large end of the tooth and is the same as the depth of teeth in spur wheels, see table, page 122.

Care must be taken that the back lash in the index pointer and the cross slide screw is taken up.

In ordering cutters for miter and bevel gears, state pitch, number of teeth, and the length of the face of tooth. For a pair of bevel gears, two cutters of different shapes are required on account of the difference in the number of teeth in the large and small gears.

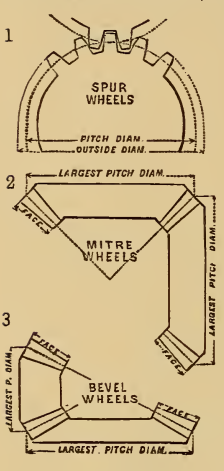

Fig. 44 shows the direction of motion of the cutter and the table.

A paper was read at a meeting of the American Society of Mechanical Engineers, held in December 1896, on cutting bevel and miter gears. This paper was prepared by Forrest R. Jones and Arthur L. Goddard, and was published later in the American Machinist of January 21, 1897. Their experimental investigations were made to find a graphical method for determining those operations which must otherwise be fixed by trial.

WORM WHEELS.

In cutting worm wheels, the work is fed up vertically into the cutter to the proper depth. It is also necessary to swivel the table. Before swiveling the table, the cutter is set central with the work. The angle to which the table must be set depends upon the pitch and the diameter of the worm. Fig. 46 shows a graphical method for finding this angle.

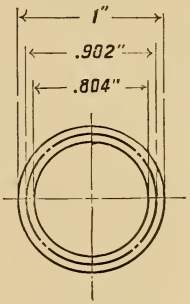

FIG. 45.

For example, take a worm whose pitch is 7 threads per inch and whose outside diameter is one inch, see Fig. 45. Lay off the distance A B, Fig. 46, equal to $\frac{1}{7}$ of an inch. The distance A C at right angles to A B is the result obtained by multiplying the pitch diameter of worm, .902 by 3.14. Connect points C and B with a straight line, and the angle A C B shows the number of degrees through which the table must be swiveled, which is 3 degrees in this example.

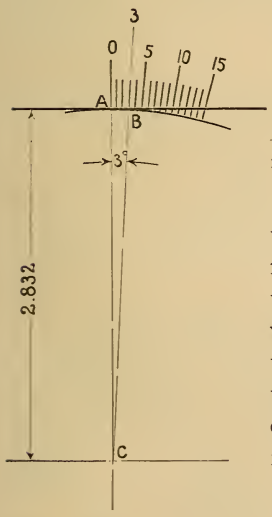

FIG. 46.

1.000 inch = outside diameter.
.098 " = depth of tooth.
.902 " = diameter of pitch circle.
3.14
2.83228 inch = length A C of pitch circle.

For right thread worm wheels, swivel the table to the right, for left thread worm wheels, swivel the table to the left, facing either end of milling machine table.

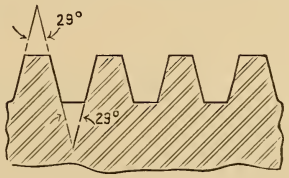

FIG. 47.

The angle of the thread of the worm should be 29°, as shown in Fig. 47.

To find the DIAMETER of a worm wheel at the THROAT, Fig. 48, when the number of teeth in the worm wheel and the number of threads per inch on the worm are given:

Add 2 to the number of teeth in the worm wheel and multiply by .3184 and divide this result by the number of threads per inch on the worm, and the result will be the diameter of the worm wheel at the throat.

Example: Worm wheel has 40 teeth.
Worm has 6 threads per inch.

$40 + 2 = 42 \quad 42 \times .3184 = 13.3728$

$\frac{13.3728}{6} = 2.2288$ inches = diameter at the throat of the worm wheel.

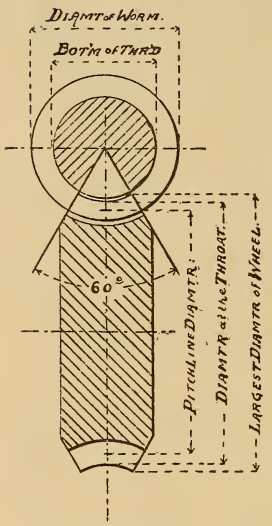

FIG. 48.

To find the NUMBER of teeth in a worm wheel, when the diameter at the throat and the pitch of worm are given. Multiply the diameter at throat by the number of threads per inch on the worm, and then multiply this product by 3.141; then substract 2 and the result will give the number of teeth.

Example:

Diameter at throat = 2.2288 inches.
Worm has 6 threads per inch.

$2.23 \times 6 = 13.38$
$13.38 \times 3.14 = 42.026$
$42.06 - 2 = 40 =$ No. of teeth.

TABLE SHOWING DEPTH OF TEETH FOR WORM WHEELS.

Threads Per Inch on Worm.	Depth.	Threads Per Inch on Worm.	Depth.	Threads Per Inch on Worm.	Depth.	Threads Per Inch on Worm	Depth.
1	0.6866	3	0.2288	7	0.0980	11	0.0623
1½	0.4577	4	0.1716	8	0.0858	12	0.0572
2	0.3433	5	0.1373	9	0.0762		
2½	0.2746	6	0.1144	10	0.0686		

SPIRAL GEAR CUTTING.

Some of the following articles on normal pitch, addendum, etc., relating to spiral gears, have been taken from Mr. George B. Grant's Hand-Book on Gears, with his kind permission.

NORMAL PITCH.—"The real pitch of the spiral gear is measured on a section that is normal to its axis, and, as in the case of the spur gear, it is found by dividing the number of teeth by the pitch diameter; but the shape of the tooth must be regulated by the normal pitch, or pitch of its normal section. The normal pitch is found by dividing the real pitch by the cosine of the angle made by the tooth spiral with the axis of the gear. Thus, if the real pitch is 5.65 and the angle of the spiral is 45°, the normal pitch is 5.65 divided by .707 or 8."

The normal pitch can also be found graphically by the following method.

Lay off A B, Fig. 49, to any convenient scale equal to the real pitch. Draw another line A C, making the angle at A equal to the angle of the spiral. Draw a line perpendicular to A B from B and let it intersect A C. The length of this oblique line A C measured to the same scale as A B will be the normal pitch.

In this example

Real pitch A B = 5.65
Angle of spiral = 45°
Normal pitch A C = 8

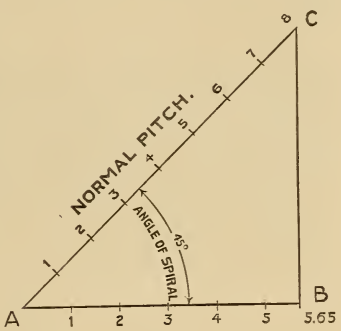

FIG. 49.

ADDENDUM.—"The addendum of the spiral gear should not be determined by its real pitch, but by its normal pitch, for it is then usually possible to mill the tooth with a milling cutter that is made for a standard spur gear. A gear of 11.3 normal pitch and 45° angle should have an addendum of $\frac{1}{11.3} = .089$."

"If the addendum is determined by the true pitch when the angle is considerable, the tooth will be long and thin."

Shaping the Tool.—"When the spiral gear is cut in a milling machine or turned in a lathe, it is necessary to give the tool the shape of the normal section to be cut, and this is most readily accomplished by shaping it for the spur gear that most nearly coincides with that normal section.

"The number of teeth in the gear that is osculatory to the normal spiral, and therefore most nearly coincides with it, is found by dividing

the actual number of teeth in the gear by the third power of the cosine of the spiral angle.

"For example, if we are to cut a gear 4″ diameter, 6 pitch, and 24 teeth, at a spiral angle of 45°, the cutter should be shaped to cut a spur-gear of $\frac{24}{.707^3} = \frac{24}{.353} = 69$ teeth of $\frac{6}{.707} = 8.5$ pitch.

"If the gear has 28 teeth of 4 pitch, and an angle of 10°, the equivalent spur-gear has 29 teeth of 4.08 pitch, as the gear varies but little from a spur-gear. If the gear is of 5 pitch, and 15 teeth, with an angle of 80°, the equivalent spur-gear has 2830 teeth of 28.7 teeth, and in general, when the gear has a great angle it is a worm, the section is practically that of a rack. Care must be taken, when the gear is a screw, and is turned in the lathe, that the tool should be set with its cutting edge normal to the thread of the screw, if it is shaped by the above rule. If the tool is set in the axial section of the screw, and it generally is, it should be shaped to the axial section of the worm and have the axial pitch and addendum. But when the lead of the thread of the screw is small compared with its diameter, the difference between the normal and axial sections is not noticeable."

When spiral gears are to be used, there are several things to be considered in their design. Sometimes a certain distance must be maintained between the centers of the two gears. In some instances, it is not necessary to put the centers of the two wheels any certain distance apart, because there is ample room for the gears to work in, and in such a case, a spur-gear cutter on hand may be used, and the problem is to determine what spiral gears can be cut with a given spur-gear cutter.

The following example shows, when the distance between the centers of the spiral gears is given, see Fig. 50, how to find

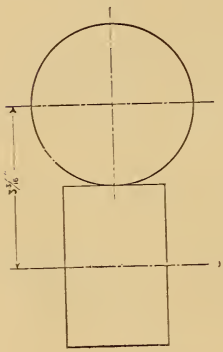

FIG. 50.

1. The Real Pitch.
2. The Normal Pitch or Pitch of Cutter.
3. Number of Teeth in Spur-Gear which is osculatory to the spiral.
4. Outside Diameter of Gear.
5. Depth of Cut.
6. Ratio of Change Gears on Dividing Head and Lead Screw.

Distance between centers $= 3\frac{3}{16}''$

Therefore pitch diameter $= 3\frac{3}{16}''$

Circumference at pitch line $= 3.1875 \times 3.1416 =$ 10.013 or 10.

Assume 18 as the number of teeth.

Then the REAL PITCH $= \frac{18}{\text{pitch diameter}} = \frac{18}{3.1875} =$ 5.65

The NORNAL PITCH $= \frac{5.65}{\text{Cos. } 45^\circ} = \frac{5.65}{.707} = 8$ pitch. $\therefore$ 8 pitch = pitch of cutter to cut gear.

NUMBER OF TEETH in spur gear which is osculatory to the spiral is $\frac{18}{.707^3} = \frac{18}{.353+} = 51$ teeth.

OUTSIDE DIAMETER = pitch diameter $+ \frac{2}{\text{Normal Pitch}} = 3\frac{3}{16} + \frac{2}{8} = 3\frac{7}{16}$.

DEPTH OF CUT $= \frac{2.157}{\text{Normal Pitch}} = .267''$.

RATIO OF CHANGE GEARS on dividing head and lead screw. The lead of a spiral of 45° always equals the circumference of the pitch diameter. In this case, the circumference of the pitch diameter is 10 inches. Therefore, the lead of the spiral is 10 inches. Gears of the same size on both lead screw and worm shaft will cut this spiral. In order that the gears may have a possible number of teeth, it is necessary that the lead shall be a number which will work in readily.

For example, if the lead is 9.6132″, then use 9.6 inches lead and change the pitch diameter. The ratio of the gears in this case is $\frac{9\ 6}{1\ 0}$ or $\frac{9.6}{10.0}$. $\frac{9.6}{10.0} = \frac{48}{50} = \frac{24}{25} = \frac{6}{5} \times \frac{4}{5}$.

Multiplying both numerator and denominator of a fraction by the same number does not change its value, therefore the product $\frac{6}{5} \times \frac{4}{5}$ is not changed in value when expressed $\frac{72}{60} \times \frac{32}{40}$ after multiplying both terms of $\frac{6}{5}$ by 12 and both terms of $\frac{4}{5}$ by 8. Again, if the lead is 7.962 use 8 for the lead and the ratio of gear on head to gear on lead screw would be $\frac{8}{10}$.

It sometimes occurs that it is not necessary to maintain a certain distance between the centers of spiral gears. In that case, spur gear cutters on hand may cut the spiral gear.

With any given spur gear cutter, it is possible to cut some spiral gear. The following example may be used as a guide for finding the spiral gear which can be cut.

In this example, a cutter 10 pitch No. 3, cutting from 35 to 54 teeth in a spur gear will be used.

Multiply the pitch 10 by the cosine of the spiral angle .707 to find the real pitch $= 10 \times .707 = 7.07$.

No. of teeth in spiral gear = No. of teeth which cutter will cut in spur gear multiplied by the cube of the cosine of the spiral angle.

No. of teeth in spiral gear $= 35 \times .707^3 = 35 \times .3533 + = 12$.

No. of teeth in spiral gear $= 54 \times .707^3 = 54 \times .3533 + = 19$.

This cutter will cut from 12 to 19 teeth in a spiral gear with a real pitch of 7.07.

Suppose that 15 teeth are cut in the gears, then $\frac{15}{7.07} = 2.121 =$ diameter at pitch circle.

Total depth of tooth $= \frac{2.157}{10} = .2157''$.

Outside diameter of wheel $= 2.121 + \frac{2}{10}$ 2.321.

$2.12 \times 3.14 = 6.656 +$ lead of required spiral, use 6.6″ lead then the ratio is $\frac{6.6}{10}$ or $\frac{66}{100}$.

Given cutter 20 pitch. No. 2. { 55 teeth / to / 134 teeth.

$20 \times .707 = 14.14 =$ real pitch.

No. of teeth in sp. gear $= 55 \times .353 + = 19$.

No. of teeth in sp. gear $= 134 \times .3533 = 47$.

$\frac{40}{14.14} = 2.828 =$ diameter of pitch circle.

Depth of cut $= \frac{2.157}{20} = .1078$.

Outside diameter $= 2.828 + \frac{2}{20} = 2.928$. $2.828 \times 3.14 = 8.879 + =$ lead of spiral, then the ratio is $\frac{8.8}{10} = \frac{88}{100} = \frac{44}{50}$.

CHANGE GEARS FOR CUTTING SPIRALS.

The worm wheel in the universal indexing and dividing head has 40 teeth; therefore, 40 revolutions of the worm are required to make one revolution of the dividing head spindle. The table lead screw has 4 threads per inch; therefore, 4 revolutions of the screw are required to move the table forward one inch. If gears of equal size were put on the lead screw and the worm shaft, to produce one revolution of the dividing head spindle, the worm shaft must be revolved 40 times. The gears being of the same size, the lead screw would also revolve 40 times and the table would travel 10 inches and these gears would give a lead of 10 inches.

To determine gears which will give a spiral of any other lead, multiply the required lead in inches by 4; this number will be the required number of revolutions of the lead screw for every 40 revolutions of the worm, necessary for one revolution of the dividing head spindle.

The ratio $\frac{\text{number of teeth in driven gears}}{\text{number of teeth in driving gears}}$ must equal $\frac{\text{4 times the lead}}{40}$

For example, to cut a spiral with a lead of 10½ inches, multiply 10½ by 4 = 42. The lead screw must, therefore, make 42 turns while the worm makes 40 turns. To accomplish this with gearing, the ratio $\frac{\text{number of teeth in driven gears}}{\text{number of teeth in driving gears}}$ must equal $\frac{42}{40}$. This ratio $\frac{42}{40}$ can be divided into two fractions without changing its value, that is $\frac{42}{40} = \frac{7}{8} \times \frac{6}{5}$. Multiplying both numerator and denominator of these fractions by some number does not change their value, that is $\frac{7}{8} \times \frac{8}{8} = \frac{56}{64}$ and $\frac{6}{5} \times \frac{8}{8} = \frac{48}{40}$.

The ratio $\frac{42}{40}$ is not changed in value if it is written in this form $\frac{56}{64} \times \frac{48}{40}$. Gears with these numbers of teeth are found among the set of change gears furnished with each universal machine. The gears having 56 and 48 teeth are the driven gears and may be arranged to have either driven from the screw, in which case, the other must be put on the worm shaft.

The gears having 64 and 40 teeth are the driving gears, and either gear may be put on the lead screw, in which case the other must drive the gear on the worm shaft.

From these examples, the following rules may be deduced :

Multiply the required lead by 4. The number thus obtained will be the numerator and 40 will be the denominator of a fraction which will give the ratio required, that is $\frac{\text{the number of teeth in driven gears}}{\text{the number of teeth in driving gears.}}$ Resolve this fraction into two fractions. Multiply the numerator and denominator of each fraction by some number (not necessarily the same number for each fraction) so as to give numbers corresponding to the number of teeth in the change gears furnished with the machine. The numbers in the numerators will represent the number of teeth in the driven gears, and the numbers in the denominators will represent the number of teeth in the driving gears.

Instead of using compound gearing, it is frequently much simpler to drive from the table screw to the worm shaft, as shown in Fig. 51.

For example, to cut a spiral with a lead of 12 inches, the ratio of the number of teeth in driven gear to the number of teeth in driving gear is $\frac{48}{40}$. If the 48 gear is fastened on the worm shaft, and the 40 gear is fastened on the table screw, the desired spiral of 12 inches lead will be produced.

Always withdraw the index plate stop before starting to cut spirals, because the index plate must be free to revolve with the index pointer. The dividing head should be placed in that slot of the table which is directly over the lead screw.

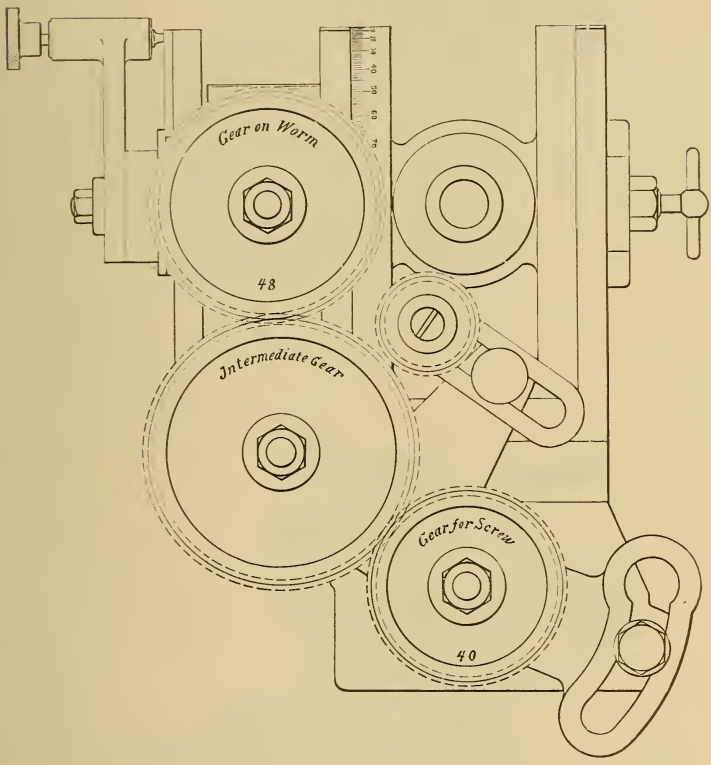

FIG. 51.

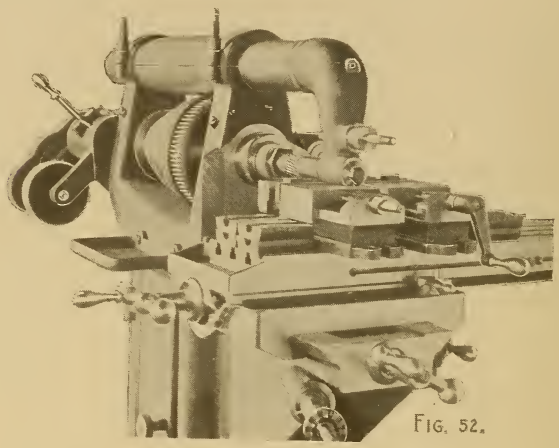

FIG. 52.

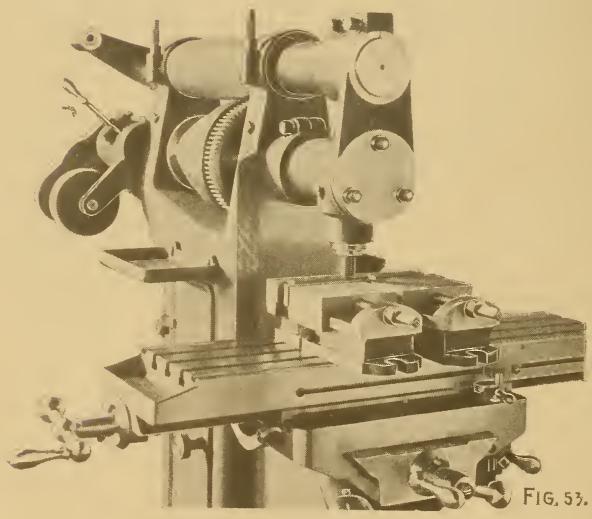

FIG. 53.

SPECIAL JIG MILLING.

When large quantities of pieces are to be milled, the cost of milling can be greatly reduced by using some special jig or device for either holding the work securely, or indexing the work rapidly. Very often, it is necessary to provide for both rapid and accurate indexing, and for firm and convenient chucking. The saving in time will more than pay for the cost of such jigs and devices.

A number of illustrations are given showing some of the methods in practical use on milling machines.

Two vises, Fig. 52, can be clamped side by side and used to good advantage. After the piece in the vise on the left is milled, the piece in the second vise can be brought up to the cutter, and while the second piece is being milled, another piece can be clamped in the first vise. In this manner, a considerable saving in time is effected.

Pieces to be milled in this way are shown on left end of table.

A similar use of two vises is shown in Fig. 53. The vertical milling attachment is used here, however. While the cut is being taken on one piece, another can be clamped in the second vise.

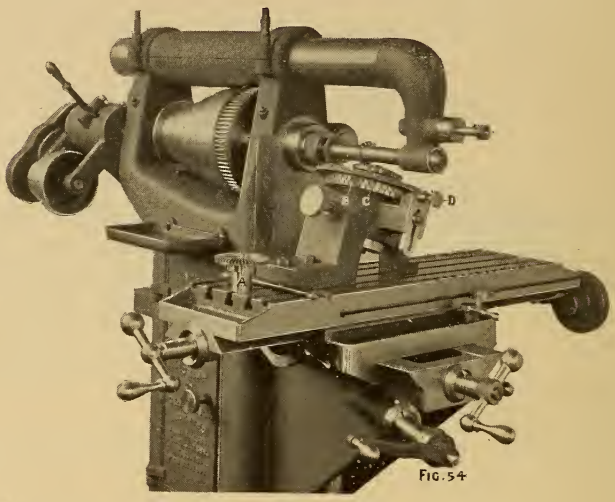

FIG. 54

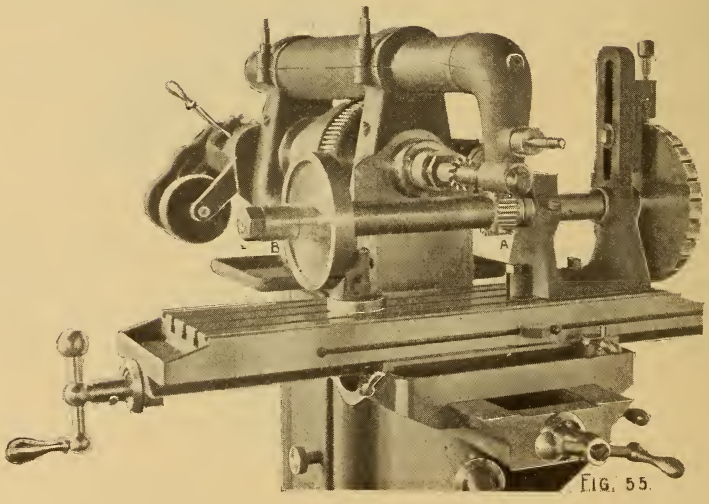

FIG. 55.

Fig. 54 shows a device for chucking and indexing bevel gears. The gear is shown at A. Two index plates B and C, are used for the first and second cuts. The proper adjustment of the cross slide must be made for these cuts. The index pin D, can be adjusted up and down to work in either plate. The hub of the gear is let down into the jig, and in this way, the gear is well supported against the strain of the cut.

NOTE.—These gears are 12 pitch and are fed to the cutter at the rate of .057 inches per turn of the spindle.

It is difficult to cut accurately on a gear cutter the pinion of a back gear when both gears are cast in one piece, because the pinion is at the outer end of the arbor and not well supported.

Fig. 55 shows a method of cutting the pinion of a back gear on a milling machine. The spindle of the dividing head stock is made long enough to extend through the back gear for holding it. Suitable collars are provided at B to accommodate different lengths of back gears. The pinion A is thus brought very close to the dividing head stock and accurate work can be done at a high rate of feed. In this manner, a 6 pitch pinion can be cut at the rate of .076 inches for one turn of the cutter spindle.

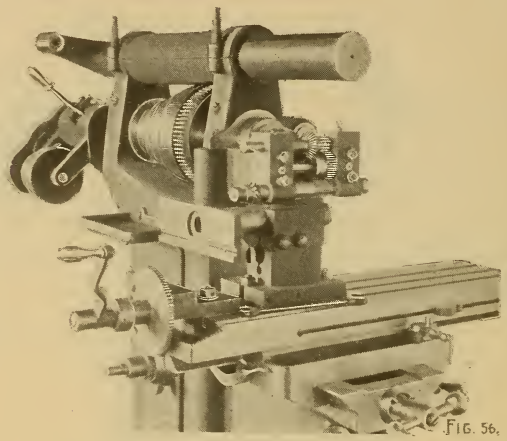

FIG. 56.

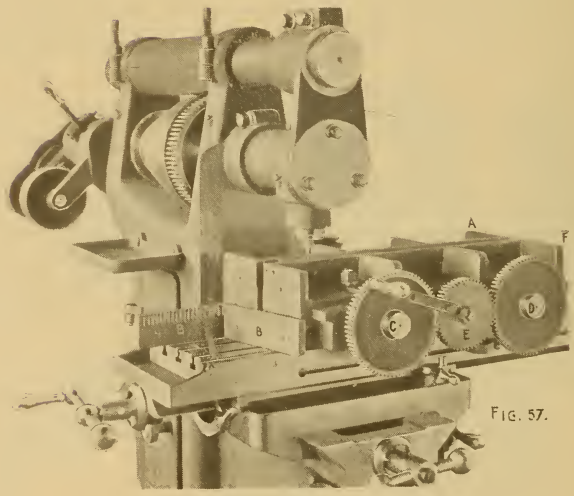

FIG. 57.

Rack-cutting is illustrated in Fig. 56. Three cutters are used on the cutter spindle. An indexing attachment is fastened to the table. To move the table to the right for new cuts, the pin B is withdrawn, the large gear wheel is turned by the crank C until the pin B again enters the slot. When the pin strikes the end of the slot, the table will have been moved to the right, the required amount for a series of three teeth by one turn of the crank C.

A devise for milling the two sides of a form for bullet molding is shown in Fig. 57. The two sides B, B, of the form are held by screws to the jaws A and F. By revolving the intermediate gear E, the gears which are fastened on shafts C and D are revolved, bringing both jaws up to the cutter at the same time. On the shafts C and D are turned both right and left hand threads which mesh in nuts under the jaws A and F.

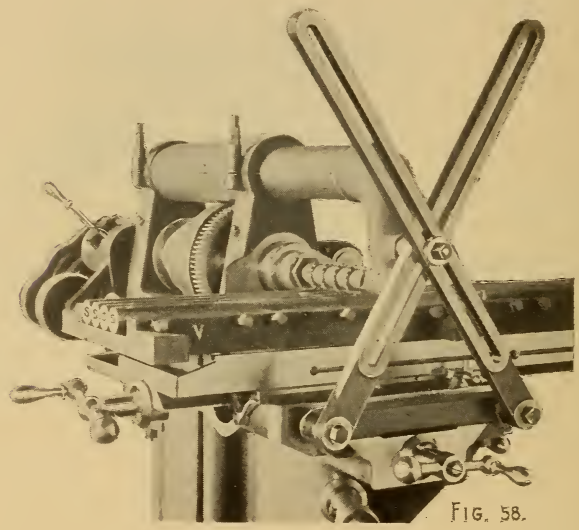

FIG. 58.

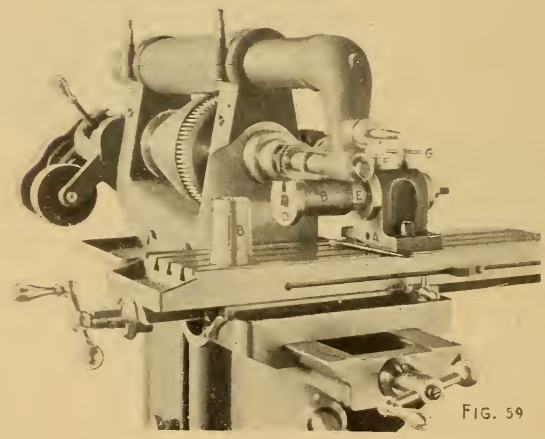

FIG. 59

A number of shafts can be splined at one time by clamping them as shown in Fig. 58.

A vise V, large enough to take in the four shafts, s, s, s, s, is clamped to the milling machine table. The four cutters are placed on the arbor at the proper distances from each other. The overhanging arm braces, B, B, combines the outer support of arbor with the knee.

The back box, B, Fig. 59, for the milling machine spindle is made of phosphor bronze. It has a groove milled in the outside for an oil wick and through this same groove is cut a narrow saw slot to allow the oil to pass through. The box is split through its entire length on the side opposite the groove. These three operations are performed with one chucking of the work and without removing the cutters from the arbor. The box B is put on a spindle E which revolves in the head A, and is clamped firmly by the washer D and the bolt C C. The index plug F is used to bring the box to its proper position for a cut. The thumb screw G is used for clamping the spindle E firmly in the head A. The table must be moved in or out to bring the cutter to be used central with the work.

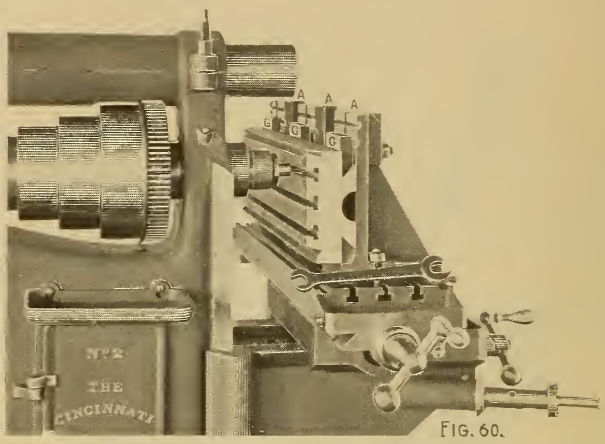

FIG. 60.

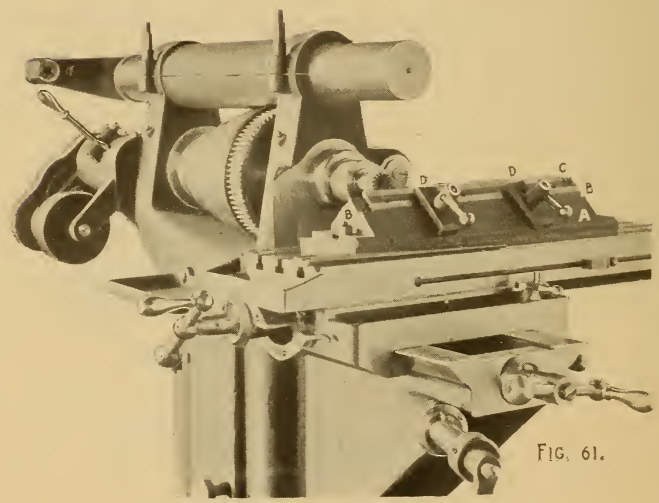

FIG. 61.

The angles A, A, A, Fig. 60, are used to hold the milling machine tables while cutting the T slots. The angles are made large enough to take in all the different widths of tables. The lower part of each angle has a 45 degree V planed in it, to correspond with the V's on the tables. The gibs, G, G, G, which are made to take in different widths of tables, are used to clamp the table firmly to the angles.

A tedious and lengthy operation is the planing of taper gibs. To overcome a very unsatisfactory process on the planer, the jig shown in Fig. 61 was devised for milling taper gibs. This jig is simply an angle A with a recess B, B, planed in it to hold the gib at the proper angle. Two clamping screws D, D, are used to clamp the gib on the angle.

ERECTION AND CARE OF THE MACHINE.

Position of Countershaft Cone Pulley.

The machine should be set level and upon a foundation as solid as can be secured. The countershaft cone pulley should be directly over the milling machine driving cone, so that the driving belt does not strike the cylindrical brace between the upright supports for the overhanging arm.

Shifter.

The handle of the shifter should be to the left of the machine and near the middle of the driving cone.

Driving Belts.

Both driving belts should run in the same direction.

Diameter of Pulleys.

To find the diameter of pulley to be used on the main shaft, multiply the diameter in inches of pulley on countershaft by the specified number of revolutions per minute of the countershaft, and divide this product by the number of revolutions per minute of the main shaft; the result will be the diameter in inches of the pulley required on the main shaft.

For example, the pulleys on the countershaft of the No. 1 Universal are 12 inches diameter and run at 80 and 150 revolutions per minute; a certain main shaft runs at 140 revolutions per minute. Then $\frac{12 \times 80}{140} = 6\frac{6}{7}$ inches, or about 7 inches is the diameter of pulley to be used on the main shaft to obtain 80 revolutions per minute of the countershaft. The other countershaft pulley runs at 150 revolutions per minute, and hence the diameter of the pulley required on the main shaft is $\frac{12 \times 150}{140} = 12\frac{6}{7}$ inches or about 13 inches.

A blue print similar to Fig. 62, showing the arrangement of the countershaft is sent with each machine.

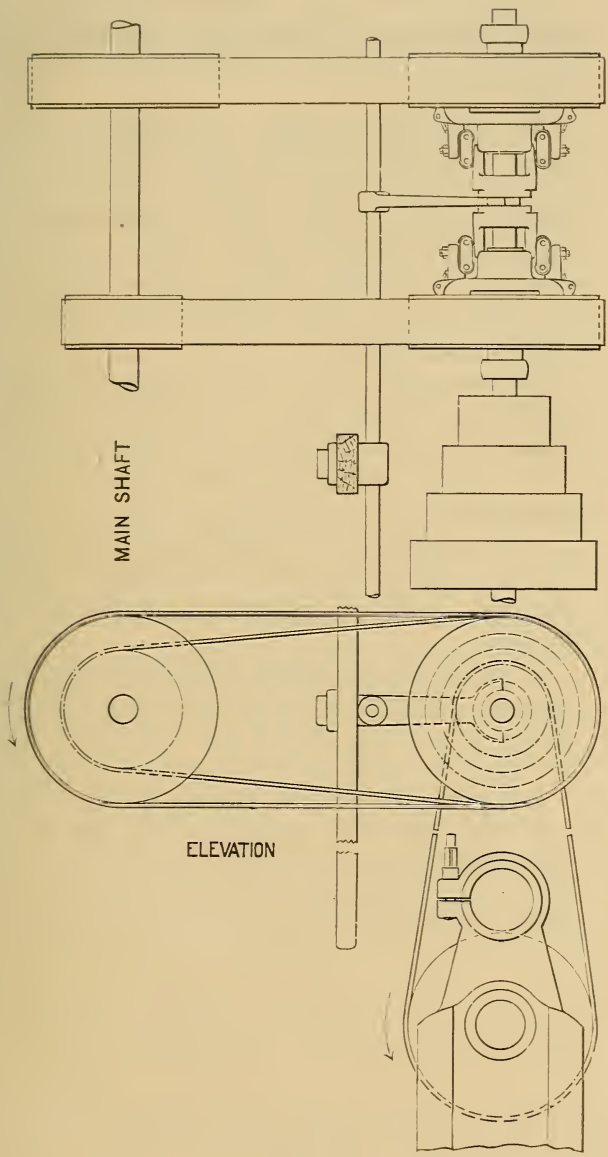

FIG. 62.

On both disks of the countershaft clutch pulleys, the word "oil" is cast in raised letters. Near these letters, an oil hole is drilled to permit the oiling of the pulleys while running.

The durability, accuracy, and efficiency of a fine machine, depends to a great extent upon proper lubrication. Therefore, the operator should become acquainted with *all* oiling places and be careful not to neglect those plainly in sight. The interior working parts and the table bearings are oiled through holes in the table marked "oil" when the table is run to the right its full length.

We advise the use of a good grade of mineral oil, as animal oils contain more or less gummy substances, which in due time clog up in the oil channels.

The ends of the arbor collars should be kept perfectly clean.

As all machines are carefully adjusted before shipment, no adjustment will be necessary for some time. When the spindle is adjusted, it should turn readily by hand.

To obtain the best results when adjustment becomes necessary, the construction and principles of the machine should be carefully studied and understood before removing or taking up the wear of any part of the machine.

It is necessary that the bushing in the overhanging arm should be closely adjusted to the outer end of the arbor, and that the arbor should be of as large diameter and as short as possible. The cutter should be as close to the nose of the spindle as the work will permit.

DESIGN, FEATURES, WORKMANSHIP.

The true principles of design were inquired into when the construction of these machines was undertaken. The proper selection of material and a correct disposal of it to the best advantage, the relative efficiencies of the different kinds of gear transmission especially for the operation of the feed mechanism, were made subjects of separate and extensive inquiry, which required much tedious and costly experimentation. The power required for driving a machine is frequently an important item of expense, especially where a shop rents power or uses an electric motor to drive the machine. Power is sometimes limited, and must be used economically. This fact makes it important that the machines used in such shops should be designed with a careful consideration of their power efficiencies in each particular.

Efficiency.

The feed mechanism has always been regarded, even with the fine-feed practice of the past, too weak and inefficient. Since such surprising advantages have been shown with coarser feeds, the former feed mechanisms have proven entirely inadequate. The great variety of work now done on milling machines, requiring both coarse and fine feeds, demands a wide range of feed. Recognizing this fact, the back-geared machines, with their greater number of spindle speeds, have been designed to give 12 changes of feed for each spindle speed, and those machines without back gears have 8 changes of feed for each spindle speed. The table feed is given in thousandths of an inch travel for each turn of the spindle. The Nos. 0 and 1 Plain have a range from .005″ to .100″; all other Plain machines have a range from .006″ to .187″.

Feed.

Number of Changes of Feed.

The No. 1 Universal has a range from .004″ to .187″ and all other Universal machines have a range from .005″ to .150″.

A pointer on the end of the lever on the gear box indicates on a dial the feed at which the machine is being operated. Throwing this lever from one side to the other, increases or diminishes the rate of the feeds between two and three times.

Heretofore, with the narrow range of feeds on milling machines, it was impossible to accommodate the large range of cutter diameters which are required in every day practice.

These cutters may range from less than $\frac{3}{8}''$ to more than 6″ diameter.

A very large part of the total power required for the machine is used in feeding the work to the cutter, and hence careful attention to the character and efficiency of the gearing and transmission devices used for the feed, is of high importance.

Comment on Worm Gearing.

Worm gearing is largely used for the transmission of power to the feeds. For fixed speeds of small range, worm gearing may serve certain purposes, accompanied, however, by sacrifices of power. But where the power as well as the speed of transmission must have a large variation, especially where the coarsest feed is more than thirty times as fast as the finest feed, the use of worm gearing would waste an enormous amount of power.

Geo. B. Grant, says: "The combination known as worm gear and worm is much used for obtaining slow and powerful motions. *It is also too much used for wasting power and wearing itself out*, for its friction is very great, and consumes one-quarter to two-thirds of the power received."

The efficiency of worm gearing is lowest for slow speeds (often not more than 40 per cent.) while the highest speed is soon reached by the tendency to abrasive cutting of the teeth. Cast Iron worm gears should not have a sliding speed for their teeth greater than two hundred feet per minute, and with the most favorable metals in contact, this speed should not be increased too much.

The practical usefulness of speed range is therefore limited. On the other hand, the efficiency of spur gearing usually ranges from 86 to 99 per cent. at almost any speed which might be used."

Perhaps the most extensive experiments ever made to determine the relative efficiencies of worm and other toothed gearing, were those by Wm. Sellers & Co., and these have been very carefully described in a paper by Wilfred Lewis, printed in the Transactions of the American Society of Mechanical Engineers, Vol. VII. A very comprehensive extract from this paper is given in George B. Grant's "Treatise on Gears," from which the following abridgment and chart have been taken. We are indebted to Mr. Grant for this matter.

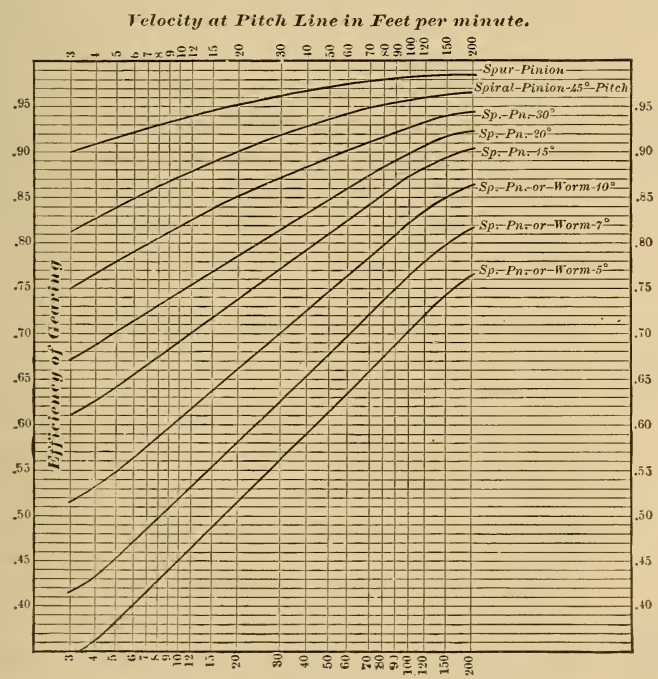

FIG. 63.

"The diagram, Fig. 63, shows that a common cast iron spur gear and pinion on parallel shafts, have an efficiency of from 90 to 99 per cent., according to the speed at which they are working; that a spiral pinion of 45°, working in a spur gear, with shafts at 45°, has an efficiency of from 81 to 97 per cent.; that the efficiency decreases as the angle of the shaft increases, until, for a worm of a spiral angle of 5°, at a shaft angle of 85°, it goes as low a 34, and does not rise higher than 77 per cent. This includes the waste of power at the shaft bearings, as well as that at the teeth of the gears.

"The efficiency is lowest for slow speeds, and rises with the speed. The diagram may be relied upon to give its true value, under ordinary conditions, within five per cent."

Screw Feed.

We have adopted the screw feed on account of its steady and uniform motion. With it, when adjusting work to the cutter, accidental catching of the cutter on the work (a danger incident to rack feed) is avoided. It also affords a ready control where delicate feeding by hand is required. With the quick return gear on the right end of the table, the screw can be rapidly turned in either direction, and thus with a handle at each end, the operator is enabled to adjust the table while standing on either side of the machine.

When machines are equipped, or intended to be equipped, with a vertical or a rack cutting attachment, nothing will answer better than the screw feeding table. For vertical milling, the screw feed is desirable, for the reason stated before. For rack cutting on the milling machine, the screw is used for making accurate divisions for the rack teeth. The screw can also be used for making exact divisions on a great variety of other work.

A number of distinctive features have been embodied in the design of these machines. Absolute accuracy is secured in the alignment of the main spindle, and facilities for maintaining this adjustment are provided. Large journal

bearing surfaces are used, and the front box (tapered both inside and outside) is made of cast iron, lined with the best Babbitt metal, thoroughly compressed and secured; the superiority of such a bearing is well recognized. The back bearing is made of phosphor bronze, turned to fit a taper bored seat in the column. Both boxes are provided with means for compensation as wear takes place.

The end of the cutter-arbor is made cylindrical, and the bushing in the overhanging arm for its support, is constructed so as to admit of being closed in concentrically as wear takes place. Three key-ways are milled in the bushing, so it can be turned one-third way round, from time to time. This is of great importance, as accurate milling and depth of cut depend upon the rigid support of the cutter arbor. If the arbor is not well supported, the cutter will chatter, and will not take heavy cuts, and the work will not be accurate.

Position of Levers and Handles.

The different levers and handles for operating the machine are so arranged to be convenient for the operator.

The handles on the shaft for elevating and the cross feed screw may be disengaged, yet remain in position for immediate use. With the handles disengaged, but still remaining on their respective shafts, there is no chance for the operator to accidentally disturb an adjustment.

Countershaft Speeds.

The double speed countershaft gives the operator two speeds of the cutter, without shifting the cone pulley belt or changing the gearing, thus allowing a heavy cut to be taken at one speed, and then a light finishing cut at a higher speed of rotation, which is often convenient and saves time.

All Universal machines are furnished with a cross feed automatic in both directions, in addition to the automatic longitudinal feed.

Automatic Cross Feed.

An automatic cross feed on the No. 2 and No. 3 Plain machines, and an automatic vertical feed on the No. 2 and No. 3 Plain and Universal machines, can be furnished to

order. The cross feed is of considerable length, and power cross feed proves a great advantage in boring operations, which can readily be done on these machines.

All automatic feeds operate in either direction, and can be instantly reversed by a lever conveniently located at front of machine. This feature, on some classes of work, almost doubles the output of machines with feed for table in one direction only. The automatic trip in either direction is not confined between two dogs, but is thrown out by a dog constructed to permit a further movement by hand, without the necessity of releasing the dog.

Ball Bearings.

Ball bearings are used in the No. 3 machines on the table feed screw and on all machines on the screw for elevating. In this manner, the friction due to the thrust on the bearings of these screws is largely compensated for, and considerable efficiency is added to the power feeds and ease and sensitiveness to the hand adjustments. A hand stop for the table feed is furnished with each machine.

Workmanship.

For many years, we have made milling machines a study and their manufacture an exclusive specialty. It has been our constant purpose to produce the very best machine of its class, and we guarantee the materials and workmanship in our product to be strictly of the highest grade. All machines are subject to a careful inspection, and are belted and run before leaving the works. The table feed and the cross feed screws are provided with compensating nuts for taking up the wear. We believe that the many novel and useful features embodied in the present design, will commend them to all those seeking the largest productive capacity in the equipment of a modern machine shop.

Index Table for Universal Indexing and Dividing Head on Universal Milling Machine.

TABLES OF ANGLES AND GEARING FOR SPIRALS.

1st Intermediate Gear should pitch in the Gear for Worm. 2d Intermediate Gear should pitch in the Gear for Screw.

Pitch, in inches to one turn.	Gear on Worm.	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw.	DIAMETER OF WORK.																			
					⅛ INCH	¼ INCH	⅜ INCH	½ INCH	⅝ INCH	¾ INCH	⅞ INCH	1 INCH	1¼ INCH	1½ INCH	1¾ INCH	2 INCH	2¼ INCH	2½ INCH	2¾ INCH	3 INCH	3¼ INCH	3½ INCH	3¾ INCH	4 INCH
1.46	24	64	28	72	14¾	28	38½																	
1.67	24	64	32	72	12¾	25	34¾	43¼																
1.94	32	64	28	72	11¼	21¾	31	39	45															
2.08	24	64	40	72	10¼	20½	29½	37	43¼															
2.22	32	56	28	72	9¾	19¼	27½	35	41¼															
2.50	24	64	48	72	8¾	17	25	32	38	43¼														
2.78	40	56	28	72	8	15½	23	29½	35¼	40½	44¾													
2.92	24	64	56	72	7½	15	21¾	28¼	34	39	43¼													
3.24	40	48	28	72	6¾	13¼	19¾	25¾	31¼	36	40½	44¼												
3.70	40	48	32	72	6	11¾	17½	23	28	32½	36½	40½												
3.89	56	48	24	72	5½	11¼	16¾	22	26¾	31¼	35¼	39												
4.17	40	72	48	64	5¼	10½	15¾	20½	25¼	29½	33½	37	43¼											
4.86	40	64	56	72	4½	9	13½	17¾	22	25¾	29½	33	39	44¼										
5.33	48	40	32	72	4	8¼	12¼	16½	20¼	23¾	27¼	30½	36½	41½										
5.44	56	40	28	72	4	8	12	16	20	23½	26¾	30	36	41										

ANGLE FOR SETTING THE SWIVEL CARRIAGE.

Index Table for Universal Indexing and Dividing Head on Universal Milling Machine.

TABLES OF ANGLES AND GEARING FOR SPIRALS.

1st Intermediate Gear should pitch in the Gear for Worm. 2d Intermediate Gear should pitch in the Gear for Screw.

Pitch, in inches to one turn.	Gear on Worm.	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw.	DIAMETER OF WORK.																		
					⅛ INCH	¼ INCH	⅜ INCH	½ INCH	⅝ INCH	¾ INCH	⅞ INCH	1 INCH	1¼ INCH	1½ INCH	1¾ INCH	2 INCH	2¼ INCH	2½ INCH	2¾ INCH	3 INCH	3¼ INCH	3½ INCH	3¾ INCH	4 INCH
6.12	56	40	28	64	3½	7¼	11	14½	17¾	21	24¼	27	33	37¾	42								
6.22	56	40	32	72	3½	7	10¾	14¼	17½	20¾	23¾	26¾	32½	37¼	41½								
6.48	56	48	40	72	3¼	6¾	10¼	13½	16¾	20	23	25¾	31½	36¼	40¼	44¼							
6.67	64	48	28	56	3¼	6½	10	13¼	16½	19½	22½	25¼	30¾	35¼	39½	43½							
7.29	56	48	40	64	3	6¼	9¼	12¼	15	18	20½	23½	28½	33	37	41	44¼						
7.41	64	48	40	72	3	6	9	12	14¾	17¾	20¼	22¾	28¼	32½	36½	40¼	43¾						
7.62	64	48	32	56	2¾	5¾	8¾	11½	14½	17¼	19¾	22¼	27½	32	36	39½	43						
8.33	48	32	40	72	2½	5¼	8	10½	13¼	15¾	18¼	20½	25½	29½	33½	37	40½	43½					
9.00	72	40	28	56	2½	5	7½	10	12½	14¾	17	19¼	24	28	31¾	35¼	38½	41¼	44				
9.33	56	40	48	72	2¼	4¾	7¼	9½	11¾	14	16¼	18½	23	27	30½	34	37¼	40¼	43				
9.52	64	48	40	56	2¼	4½	7	9¼	11½	13¾	16	18¼	22½	26½	30	33½	36½	39½	42¼	45			
10.29	72	40	32	56	2	4¼	6½	8¾	10¾	12¾	15	17¼	21	24¾	28¼	31½	34½	37½	40	42½	45		
10.37	64	48	56	72	2	4¼	6½	8½	10½	12¾	14¾	17	20¼	24½	28	31¼	34¼	37¼	39¾	42¼	44¾		
10.50	48	40	56	64	2	4¼	6¼	8½	10½	12½	14½	16¾	20½	24¼	27¾	31	34	36¾	39½	42	44¼		
10.67	64	40	48	72	2	4	6¼	8¼	10¼	12¼	14¼	16½	20¼	24	27¼	30½	33½	36½	39	41½	43¾		

ANGLE FOR SETTING THE SWIVEL CARRIAGE.

Index Table for Universal Indexing and Dividing Head on Universal Milling Machine.

TABLES OF ANGLES AND GEARING FOR SPIRALS.

1st Intermediate Gear should pitch in the Gear for Worm. 2d Intermediate Gear should pitch in the Gear for Screw.

Pitch, in inches to one turn.	Gear on Worm.	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw.	DIAMETER OF WORK.																		
					⅛ INCH	¼ INCH	⅜ INCH	½ INCH	⅝ INCH	¾ INCH	⅞ INCH	1 INCH	1¼ INCH	1½ INCH	1¾ INCH	2 INCH	2¼ INCH	2½ INCH	2¾ INCH	3 INCH	3¼ INCH	3½ INCH	3¾ INCH	4 INCH
10.94	56	32	40	64	2	4	6	8¼	10¼	12	14	16¼	20	23½	26¾	30	33	35¾	38¼	40¾	43			
11.11	64	32	40	72	2	4	6	8	10	11¾	13¾	16	19¾	23	26½	29½	32½	35¼	38	40¼	42½	44¾		
11.66	56	32	48	72	1¾	3¾	5¾	7½	9½	11¼	13¼	15¼	18¾	22	25¼	28½	31¼	34	36½	39	41¼	43½		
12.00	72	40	32	48	1¾	3¾	5½	7¼	9¼	11	12¾	15	18¼	21½	24¾	27¾	30½	33¼	35¾	38	40¼	42½	44¾	
13.12	56	32	48	64	1½	3½	5¼	6¾	8½	10¼	11¾	13½	16¾	20	22¾	25¾	28¼	31	33¼	35¾	37¾	40	42	43¾
13.33	56	28	48	72	1½	3¼	5	6½	8¼	10	11½	13¼	16½	19½	22½	25½	28	30½	33	35¼	37½	39½	41½	43¼
13.71	64	40	48	56	1½	3¼	4¾	6½	8	9¾	11¼	13	16	19	22	24¾	27¼	30	32¼	34½	36½	38¾	40¾	42½
15.24	64	28	48	72	1½	3	4½	5¾	7¼	8¾	10¼	11¾	14½	17¼	20	22½	25	27¼	29½	31¾	34	35¾	37¾	39½
15.56	64	32	56	72	1¼	2¾	4¼	5¾	7¼	8¾	10	11½	14¼	17	19½	22	24½	27	29	31¼	33¼	35¼	37	39
15.75	56	64	72	40	1¼	2¾	4¼	5½	7	8½	9¾	11¼	14	16¾	19¼	21¾	24¼	26½	28¾	31	33	35	36¾	38½
16.87	72	32	48	64	1¼	2½	4	5¼	6¾	7¾	9¼	10½	13¼	15¾	18¼	20½	22¾	25	27	29¼	31¼	33¼	35	36½
17.14	64	32	48	56	1¼	2½	4	5¼	6½	7¾	9	10¼	13	15½	17¾	20¼	22¼	24¾	26¾	29	30¾	32¾	34½	36
18.75	72	32	40	48	1	2¼	3½	4¾	6	7¼	8¼	9½	12	14¼	16¼	18½	20¾	22¾	25	26¾	28½	30¼	32	33¾
19.29	72	32	48	56	1	2¼	3½	4½	5¾	7	8	9¼	11½	13¾	16	18¼	20¼	22¼	24	26	28	29¾	31½	33
19.59	64	28	48	56	1	2¼	3¼	4½	5¾	6¾	8	9¼	11½	13½	15¾	18	20	22	23¾	25¾	27½	29¼	31	32¾

ANGLE FOR SETTING THE SWIVEL CARRIAGE.

Index Table for Universal Indexing and Dividing Head on Universal Milling Machine.

TABLES OF ANGLES AND GEARING FOR SPIRALS.

1st Intermediate Gear should pitch in the Gear for Worm. 2d Intermediate Gear should pitch in the Gear for Screw.

Pitch, in inches to one turn.	Gear on Worm.	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw.	DIAMETER OF WORK.																		
					1/8 INCH	1/4 INCH	3/8 INCH	1/2 INCH	5/8 INCH	3/4 INCH	7/8 INCH	1 INCH	1 1/4 INCH	1 1/2 INCH	1 3/4 INCH	2 INCH	2 1/4 INCH	2 1/2 INCH	2 3/4 INCH	3 INCH	3 1/4 INCH	3 1/2 INCH	3 3/4 INCH	4 INCH
19.69	72	32	56	64	1	2 1/4	3 1/4	4 1/2	5 3/4	6 3/4	8	9	11 1/2	13 1/2	15 3/4	17 3/4	20	21 3/4	23 3/4	25 1/2	27 1/2	29 1/4	31	32 1/2
21.43	72	24	40	56	1	2	3 1/4	4 1/4	5 1/4	6 1/4	7 1/2	8 1/2	10 1/2	12 1/2	14 1/2	16 1/2	18 1/2	20 1/4	22	23 3/4	25 1/2	27 1/4	29	30 1/4
22.50	72	28	56	64	1	2	3	4	5	6	7	8	10	12	13 3/4	15 3/4	17 1/2	19 1/4	21	22 3/4	24 1/2	26	27 3/4	29 1/4
23.33	64	32	56	48	1	2	3	4	5	5 3/4	6 3/4	7 3/4	9 3/4	11 1/2	13 1/4	15 1/4	17	18 3/4	20 1/4	22	23 1/2	25 1/4	27	28 1/4
26.25	72	24	56	64	1	1 3/4	2 3/4	3 1/2	4 1/4	5	6	7	8 1/2	10 1/4	12	13 1/2	15	16 3/4	18 1/4	19 3/4	21 1/4	22 3/4	24 1/4	25 1/2
26.67	64	28	56	48	3/4	1 3/4	2 3/4	3 1/2	4 1/4	5	6	6 3/4	8 1/2	10	11 3/4	13 1/4	14 3/4	16 1/2	18	19 1/2	21	22 1/4	23 3/4	25 1/4
28.00	64	32	56	40	3/4	1 3/4	2 1/2	3 1/4	4	4 3/4	5 3/4	6 1/2	8	9 1/2	11 1/4	12 3/4	14 1/4	15 3/4	17 1/4	18 3/4	20	21 1/2	22 3/4	24
30.86	72	28	48	40	3/4	1 1/2	2 1/4	3	3 3/4	4 1/2	5	5 3/4	7 1/4	8 3/4	10	11 1/2	13	14 1/4	15 1/2	17	18 1/2	19 1/2	21	22
31.50	72	32	56	40	3/4	1 1/2	2 1/4	3	3 1/2	4 1/4	5	5 3/4	7 1/4	8 1/2	10	11 1/4	12 3/4	14	15 1/4	16 1/2	18	19 1/4	20 1/2	21 3/4
36.00	72	32	64	40	1/2	1 1/4	2	2 1/2	3 1/4	3 3/4	4 1/2	5	6 1/4	7 1/2	8 3/4	10	11	12 1/4	13 1/2	14 3/4	16	17	18 1/4	19 1/4
41.14	72	28	64	40	1/2	1	1 3/4	2 1/4	2 3/4	3 1/4	4	4 1/2	5 1/2	6 1/2	7 3/4	8 3/4	9 3/4	10 3/4	11 3/4	13	14	15	16	17
45.00	72	28	56	32	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	5	6	7	8	9	10	11	11 3/4	12 3/4	13 3/4	14 3/4	15 1/2
48.00	72	24	64	40	1/2	1	1 1/2	2	2 1/2	3	3 1/4	3 3/4	4 3/4	5 1/2	6 1/2	7 1/2	8 1/2	9 1/4	10 1/4	11 1/4	12	13	13 3/4	14 1/2
51.43	72	28	64	32	1/2	3/4	1 1/2	1 3/4	2 1/4	2 3/4	3	3 1/2	4 1/2	5 1/4	6	7	7 3/4	8 3/4	9 1/2	10 1/2	11 1/4	12	12 3/4	13 3/4
60.00	72	24	64	32	1/2	3/4	1 1/4	1 1/2	2	2 1/4	2 1/2	3	3 3/4	4 1/2	5 1/4	6	6 3/4	7 1/2	8 1/4	9	9 1/2	10 1/4	11	11 3/4
68.57	72	24	64	28	1/4	3/4	1	1 1/4	1 3/4	2	2 1/4	2 1/2	3 1/4	4	4 1/4	5 1/4	5 3/4	6 1/2	7 1/4	8	8 1/2	9	9 3/4	10 1/4

ANGLE FOR SETTING THE SWIVEL CARRIAGE.

TABLE USED FOR MAKING

STANDARD SPIRAL MILLING CUTTERS,

On the Universal Indexing and Dividing Head.

Diameter of Mill.	Pitch in inches to one turn	Gear on Worm.	First Intermediate Gear.	Second Intermediate Gear.	Gear for Screw.	Angle for Setting Swivel Carriage.
½	7.29	56	48	40	64	12¼
⅝	9.52	64	48	40	56	11½
¾	9.52	64	48	40	56	13¾
⅞	13.71	64	40	48	56	11¼
1	17.14	64	32	48	56	10¼
1¼	17.14	64	32	48	56	13
1½	23.33	64	32	56	48	11½
1¾	28.00	64	32	56	40	11¼
2	31.50	72	32	56	40	11¼
2¼	36.00	72	32	64	40	11
2½	36.00	72	32	64	40	12¼
2¾	48.00	72	24	64	40	10¼
3	48.00	72	24	64	40	11¼
3¼	48.00	72	24	64	40	12
3½	60.00	72	24	64	32	10¼
3¾	60.00	72	24	64	32	11
4	68.57	72	24	64	28	10¼

TABLE USED IN CONNECTION WITH THE

UNIVERSAL INDEXING AND DIVIDING HEAD

For Dividing Work from 2 to 360 Spaces.

No. of Teeth	Circle	Turns	Holes	No. of Teeth	Circle	Turns	Holes	No. of Teeth	Circle	Turns	Holes	No. of Teeth	Circle	Holes	No. of Teeth	Circle	Holes
2	any	20	..	16	24	2	12	30	24	1	8	44	66	60	64	24	15
3	18	13	6	17	34	2	12	31	62	1	18	45	54	48	65	39	24
4	any	10	..	18	18	2	4	32	28	1	7	46	46	40	66	66	40
5	any	8	..	19	38	2	4	33	66	1	14	47	47	40	68	34	20
6	18	6	12	20	any	2	..	34	34	1	6	48	24	20	70	28	16
7	28	5	20	21	42	1	38	35	28	1	4	49	49	40	72	54	30
8	any	5	..	22	66	1	54	36	54	1	6	50	30	24	74	37	20
9	18	4	8	23	46	1	34	37	37	1	3	52	39	30	75	30	16
10	any	4	..	24	24	1	16	38	38	1	2	54	54	40	76	38	20
11	66	3	42	25	30	1	18	39	39	1	1	55	66	48	78	39	20
12	24	3	8	26	39	1	21	40	any	1	..	56	28	20	80	34	17
13	39	3	3	27	54	1	26	41	41	..	40	58	58	40	82	41	20
14	49	2	42	28	42	1	18	42	42	..	40	60	42	28	84	42	20
15	18	2	12	29	58	1	22	43	43	..	40	62	62	40	85	34	16

TABLE USED IN CONNECTION WITH THE

UNIVERSAL INDEXING AND DIVIDING HEAD

For Dividing Work from 2 to 360 Spaces.

No. of Teeth	Circle	Holes	No. of Teeth	Circle	Holes	No. of Teeth	Circle	Holes	No. of Teeth	Circle	Holes	No. of Teeth	Circle	Holes
86	43	20	115	46	16	155	62	16	192	24	5	245	49	8
88	66	30	116	58	20	156	39	10	195	39	8	248	62	10
90	54	24	120	66	22	160	28	7	196	49	10	260	39	6
92	46	20	124	62	20	164	41	10	200	30	6	264	66	10
94	47	20	130	39	12	165	66	16	205	41	8	270	54	8
95	38	16	132	66	20	168	42	10	210	42	8	272	34	5
96	24	10	135	54	16	170	34	8	215	43	8	280	28	4
98	49	20	136	34	10	172	43	10	216	54	10	290	58	8
100	30	12	140	28	8	176	66	15	220	66	12	296	37	5
104	39	15	144	18	5	180	54	12	224	28	5	300	30	4
105	42	16	145	58	16	184	46	10	230	46	8	310	62	8
108	54	20	148	37	10	185	37	8	232	58	10	330	66	8
110	66	24	150	30	8	188	47	10	235	47	8	360	54	6
112	28	10	152	38	10	190	38	8	240	66	11	...	..	..

TABLE FOR CUTTING RACKS—Using the Screw in Table for Making Divisions.

PITCH 2		PITCH 2¼		PITCH 2½		PITCH 2¾		PITCH 3		PITCH 3½		PITCH 4		PITCH 5		PITCH 6		PITCH 7		PITCH 8		PITCH 9	
Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Rev	Degrees	Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Rev.	Degrees
6	71	5	146	5	7	4	142	4	47	3	148	3	35	2	128	2	24	1	199	1	143	1	99
6	142	5	42	5	14	4	34	4	94	3	46	3	70	2	6	2	48	1	148	1	36	1	198
6	213	5	188	5	21	4	176	4	141	3	194	3	105	2	134	2	72	1	97	1	179	1	47
6	34	5	84	5	28	4	68	4	188	3	92	3	140	2	12	2	96	1	46	1	72	1	146
6	105	5	230	5	35	4	210	4	235	3	240	3	175	2	140	2	120	1	245	1	215	1	245
6	176	5	126	5	42	4	102	4	32	3	138	3	210	2	18	2	144	1	194	1	108	1	94
6	247	5	22	5	49	4	244	4	79	3	36	3	245	2	146	2	168	1	143	1	1	1	193
6	68	5	168	5	56	4	136	4	126	3	184	3	30	2	24	2	192	1	92	1	144	1	42
6	139	5	64	5	63	4	28	4	173	3	82	3	65	2	152	2	216	1	41	1	37	1	141
6	210	5	210	5	70	4	170	4	220	3	230	3	100	2	30	2	240	1	240	1	180	1	240

DIRECTIONS.—For example: to cut a 32 pitch rack, adjust the work to the cutter, and set the index on dial plate of table feed-screw at zero.

For the next tooth move the table to 98 degrees, for the following tooth to 196 degrees, and so on until you reach the last number in above scale; then set the index at zero, without moving the work, and commence with 98 again, continuing as before.

For Pitch, where one or more revolutions are required, it is understood to make the number of revolutions for each tooth, and the necessary number of degrees beyond.

TABLE FOR CUTTING RACKS—Using the Screw in Table for Making Divisions.

PITCH 10		PITCH 11		PITCH 12		PITCH 14	PITCH 16	PITCH 18	PITCH 20	PITCH 22	PITCH 24	PITCH 26	PITCH 28	PITCH 30	PITCH 32	PITCH 36	PITCH 40	PITCH 48
Rev.	Degrees	Rev.	Degrees	Rev.	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
1	64	1	36	1	12	224	196	175	157	143	131	121	112	105	98	87	79	65
1	128	1	72	1	24	198	142	100	64	36	12	242	224	210	196	174	158	130
1	192	1	108	1	36	172	88	25	221	179	143	113	86	65	44	11	237	195
1	6	1	144	1	48	146	34	200	128	72	24	234	198	170	142	98	66	10
1	70	1	180	1	60	120	230	125	35	215	155	105	60	25	240	185	145	75
1	134	1	216	1	72	94	176	50	192	108	36	226	172	130	88	22	224	140
1	198	1	2	1	84	68	122	225	99	1	167	97	34	235	186	109	53	205
1	12	1	38	1	96	42	68	150	6	144	48	218	146	90	34	196	132	20
1	76	1	74	1	108	16	14	75	163	37	179	89	8	195	132	33	211	85
1	140	1	110	1	120	240	210	250	70	180	60	210	120	50	230	120	40	150

DIRECTIONS.—For example: to cut a 32 pitch rack, adjust the work to the cutter, and set the index on dial plate of table feed-screw at zero.

For the next tooth move the table to 98 degrees, for the following tooth to 196 degrees, and so on until you reach the last number in above scale; then set the index at zero, without moving the work, and commence with 98 again, continuing as before.

For Pitch, where one or more revolutions are required, it is understood to make the number of revolutions for each tooth, and the necessary number of degrees beyond.

TABLE SHOWING DEPTH OF SPACE AND THICKNESS OF TOOTH IN SPUR WHEELS,

WHEN CUT WITH

STANDARD INVOLUTE GEAR CUTTERS.

Pitch of Cutter.	Depth to be cut in Gear.	Thickness of Tooth at Pitch Line.	Pitch of Cutter.	Depth to be cut in Gear.	Thickness of Tooth at Pitch Line.
2	1.078 in.	.785 in.	12	.180 in.	.131 in.
2¼	.958	697	14	.154	.112
2½	.863	.628	16	.135	.098
2¾	.784	.570	18	.120	.087
3	.719	523	20	.108	.079
3½	.616	.448	22	.098	.071
4	.539	.393	24	.090	.065
5	.431	.314	26	.083	.060
6	.359	.262	28	.077	.056
7	.307	.224	30	.072	.052
8	.270	.196	32	.067	.049
9	.240	.175	36	.060	.044
10	.216	.157	40	.054	.039
11	196	143	48	.045	.033

COMPARATIVE TABLE OF

CIRCULAR AND DIAMETRAL PITCH.

Diametral Pitch.	Circular Pitch.	Circular Pitch.	Diametral Pitch.
2	1.571 inch.	2 inch.	1 571
2¼	1.396	1⅞	1.676
2½	1.257	1¾	1.795
2¾	1.142	1⅝	1.933
3	1.047	1½	2.094
3½	.898	1 7/16	2.185
4	.785	1⅜	2 285
5	.628	1 5/16	2 394
6	.524	1¼	2.513
7	.449	1 3/16	2.646
8	.393	1⅛	2.793
9	.349	1 1/16	2.957
10	.314	1	3.142
11	.286	15/16	3.351
12	262	⅞	3.590
14	.224	13/16	3.867
16	.196	¾	4 189
18	.175	11/16	4.570
20	.157	⅝	5.027
22	.143	9/16	5.585
24	.131	½	6 283
26	.121	7/16	7.181
28	.112	⅜	8.378
30	.105	5/16	10.053
32	.098	¼	12.566
36	.087	3/16	16.755
40	.079	⅛	25.133
48	.065	1/16	50.266

TABLE OF DECIMAL EQUIVALENTS

OF

8ths, 16ths, 32nds and 64ths of an inch.

8ths.	32nds.	64ths.	64ths.
$\frac{1}{8} = .125$	$\frac{1}{32} = .03125$	$\frac{1}{64} = .015625$	$\frac{33}{64} = .515625$
$\frac{1}{4} = .250$	$\frac{3}{32} = .09375$	$\frac{3}{64} = .046875$	$\frac{35}{64} = .546875$
$\frac{3}{8} = .375$	$\frac{5}{32} = .15625$	$\frac{5}{64} = .078125$	$\frac{37}{64} = .578125$
$\frac{1}{2} = .500$	$\frac{7}{32} = .21875$	$\frac{7}{64} = .109375$	$\frac{39}{64} = .609375$
$\frac{5}{8} = .625$	$\frac{9}{32} = .28125$	$\frac{9}{64} = .140625$	$\frac{41}{64} = .640625$
$\frac{3}{4} = .750$	$\frac{11}{32} = .34375$	$\frac{11}{64} = .171875$	$\frac{43}{64} = .671875$
$\frac{7}{8} = .875$	$\frac{13}{32} = .40625$	$\frac{13}{64} = .203125$	$\frac{45}{64} = .703125$
16ths.	$\frac{15}{32} = .46875$	$\frac{15}{64} = .234375$	$\frac{47}{64} = .734375$
$\frac{1}{16} = .0625$	$\frac{17}{32} = .53125$	$\frac{17}{64} = .265625$	$\frac{49}{64} = .765625$
$\frac{3}{16} = .1875$	$\frac{19}{32} = .59375$	$\frac{19}{64} = .296875$	$\frac{51}{64} = .796875$
$\frac{5}{16} = .3125$	$\frac{21}{32} = .65625$	$\frac{21}{64} = .328125$	$\frac{53}{64} = .828125$
$\frac{7}{16} = .4375$	$\frac{23}{32} = .71875$	$\frac{23}{64} = .359375$	$\frac{55}{64} = .859375$
$\frac{9}{16} = .5625$	$\frac{25}{32} = .78125$	$\frac{25}{64} = .390625$	$\frac{57}{64} = .890625$
$\frac{11}{16} = .6875$	$\frac{27}{32} = .84375$	$\frac{27}{64} = .421875$	$\frac{59}{64} = .921875$
$\frac{13}{16} = .8125$	$\frac{29}{32} = .90625$	$\frac{29}{64} = .453125$	$\frac{61}{64} = .953125$
$\frac{15}{16} = .9375$	$\frac{31}{32} = .96875$	$\frac{31}{64} = .484375$	$\frac{63}{64} = .984375$

TABLE OF DECIMAL EQUIVALENTS

OF

MILLIMETRES AND FRACTIONS OF MILLIMETRES.

mm.	Inches.	mm.	Inches.	mm.	Inches.
$\frac{1}{50}$	= .00079	$\frac{26}{50}$	= .02047	2	= .07874
$\frac{2}{50}$	= .00157	$\frac{27}{50}$	= .02126	3	= .11811
$\frac{3}{50}$	= .00236	$\frac{28}{50}$	= .02205	4	= .15748
$\frac{4}{50}$	= .00315	$\frac{29}{50}$	= .02283	5	= .19685
$\frac{5}{50}$	= .00394	$\frac{30}{50}$	= .02362	6	= .23622
$\frac{6}{50}$	= .00472	$\frac{31}{50}$	= .02441	7	= .27559
$\frac{7}{50}$	= .00551	$\frac{32}{50}$	= .02520	8	= .31496
$\frac{8}{50}$	= .00630	$\frac{33}{50}$	= .02598	9	= .35433
$\frac{9}{50}$	= .00709	$\frac{34}{50}$	= .02677	10	= .39370
$\frac{10}{50}$	= .00787	$\frac{35}{50}$	= .02756	11	= .43307
$\frac{11}{50}$	= .00866	$\frac{36}{50}$	= .02835	12	= .47244
$\frac{12}{50}$	= .00945	$\frac{37}{50}$	= .02913	13	= .51181
$\frac{13}{50}$	= .01024	$\frac{38}{50}$	= .02992	14	= .55118
$\frac{14}{50}$	= .01102	$\frac{39}{50}$	= .03071	15	= .59055
$\frac{15}{50}$	= .01181	$\frac{40}{50}$	= .03150	16	= .62992
$\frac{16}{50}$	= .01260	$\frac{41}{50}$	= .03228	17	= .66929
$\frac{17}{50}$	= .01339	$\frac{42}{50}$	= .03307	18	= .70866
$\frac{18}{50}$	= .01417	$\frac{43}{50}$	= .03386	19	= .74803
$\frac{19}{50}$	= .01496	$\frac{44}{50}$	= .03465	20	= .78740
$\frac{20}{50}$	= .01575	$\frac{45}{50}$	= .03543	21	= .82677
$\frac{21}{50}$	= .01654	$\frac{46}{50}$	= .03622	22	= .86614
$\frac{22}{50}$	= .01732	$\frac{47}{50}$	= .03701	23	= .90551
$\frac{23}{50}$	= .01811	$\frac{48}{50}$	= .03780	24	= .94488
$\frac{24}{50}$	= .01890	$\frac{49}{50}$	= .03858	25	= .98425
$\frac{25}{50}$	= .01969	1	= .03937	26	=1.02362

10 mm. = 1 Centimeter = 0 3937 inches.
10 cm. = 1 Decimeter = 3.937 "
10 dm. = 1 Meter = 39.37 "
25.4 mm. = 1 English Inch.

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